WATER WORKS & SEWERAGE

Only CHAPMAN'S Cone Valve *GIVES YOU THESE*

6 BONUSES

1. No obstruction to flow . . . waterway of valve is same diameter as pipe.
2. Plug is fully seated, open or closed . . . all seats are fully protected.
3. Valve is self-cleaning . . . no chance of fouling.
4. Automatic valve unwedges, rotates, and rewedges the plug.
5. Positive, easy closing prevents surging, and wear on seats.
6. Valve is dependable for either regular or emergency duty.

Chapman builds this unique plug-type Cone Valve for manual, hydraulic, or electric operation . . . with the particular type of control best suited to the individual installation. And *you* can get these six exclusive Chapman advantages on any water, sewage, air or gas service. Check with Chapman *now,* on your own requirements.

The CHAPMAN VALVE Mfg. Co.

INDIAN ORCHARD, MASS.

THE WHEELER False Filter Bottom

AVOIDS CRITICAL MATERIALS

Requires less than four pounds of reinforcing steel per square foot of area.

A PERMANENT POST-WAR INVESTMENT

Constructed of concrete and porcelain throughout for permanence.

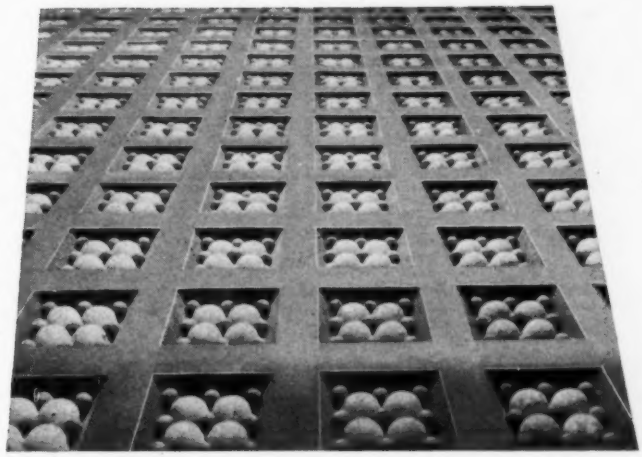
PERFECT WASH WATER DISTRIBUTION

Equal distribution assured to each square foot of filter area.

NON-CORROSIVE

Cannot rust or tuberculate as the water does not contact any ferrous metals.

This name plate is our pledge of cooperation—of adherence to specifications—of quality of materials—of excellence of workmanship—of continuing interest long after the contract price has been paid.



In most cases of substitution for critical materials some sacrifice must be made in efficiency or durability. Here, however, the Engineer may avoid critical metal and, at the same time, enhance both the efficiency and durability of the whole underdrainage system. No more efficient or more durable filter underdrainage system than the Wheeler False Filter Bottom has yet been devised.

To date we have completed, or have under contract, forty installations of Wheeler False Filter Bottoms in plants directly associated with the war effort. The combined daily capacity of these installations is 350,000,000 gallons. The smallest has a rated capacity of 150,000 gallons per day, and the largest 47,000,000 gallons per day.

Write us for technical information.

MECHANICAL EQUIPMENT BY ROBERTS FILTER MFG. CO.
607 COLUMBIA AVE.
DARBY, PENNA.

WATER WORKS & SEWERAGE, June, 1943. Volume 90. Number 6. Published monthly by Gillette Publishing Co., 330 South Wells Street, Chicago, Ill. Per copy, 25c. Subscription rate, United St ates, $2.00 per year; Canada, $2 00 per year; Foreign, $3.00 per year. Entered as Second Class Matter, June 2, 1931, at the Post Office at Chicago, Ill., under act of March 3, 1879.

LEADITE

Trade Mark Registered U.S. Pat. Office

The Pioneer Self-Caulking Jointing Material for Bell and Spigot Water Pipe

Products

LEADITE and the following tools and equipment for use with LEADITE:

BRAIDED JUTE, JOINT RUNNERS, GASOLINE and WOOD BURNING MELTING FURNACES, POURING LADLES, POURING POTS, YARNING IRONS and METAL POURING GATES.

Description

Leadite is principally used for making joints in cast iron bell and spigot water mains; is shipped in powder form in sacks containing 100 pounds.

Users

Water works superintendents, engineers, contractors, mines, railroads and industrial plants all over the world use Leadite. Thousands of miles of pipe jointed with Leadite are in service.

Method of Use

The joint space is first "yarned" and the Leadite is melted and poured into the joint, but requires no caulking. Leadite melts at approximately 250° F. Lead melts at approximately 620° F.

Comparative Quantities

One hundred pounds of Leadite are equivalent to approximately four hundred pounds of pig lead based on the joints being made the same depth with either material. It will be easy to figure the approximate quantity of Leadite requird for any given quantity of pipe by referring to our Reference Table, copy of which we shall gladly send to you upon request.

Comparative Cost

Under normal conditions, the economies effected by the use of Leadite save approximately 50% to 75% over the method which requires caulking, owing to the saving effected in material and labor.

Saving

Because Leadite saves on the items of caulking charges, digging of large bell-holes and reduces cost of trench pumping to a minimum, Leadite eliminates most every superfluous operation in jointing cast iron water mains, thus permitting the work to be completed with the least amount of effort.

Tools

As no caulking is required, fewer tools are needed.

No Caulking

Leadite joints require no caulking because Leadite adheres to the pipe from the yarn or jute out to face of bell, making a watertight bond. However, a Leadite joint may be melted or cut out at any time if desired in making connections, etc.

Durability

Leadite has been tested and used for more than 40 years and experience has proven that Leadite joints improve with age.

Expansion and Vibration

Leadite is used with excellent results under railroad tracks, highways and over and under bridges where severe vibration has demonstrated the value of using Leadite on this class of work.

Utility

Leadite is very easy to handle. It is used on all sizes of pipe from four to eighty-four inches in diameter and under all conditions and pressures encountered in water works construction.

Electrolysis

Leadite resists electrolysis.

Damage Suits

Claims for damages caused by joints blowing out are reduced because Leadite joints, if properly made, will not blow out under any pressure common in water works construction.

Transportation

Considerable freight charges are saved because Leadite is light in weight. This also means a saving in cartage and handling on the work because you move approximately one-fourth the weight of jointing material.

Delivery

We make prompt shipments of Leadite in any quantities from stock.

Fuel

Saves fuel because you melt approximately one pound of material instead of four, and less heat is required to melt Lead.

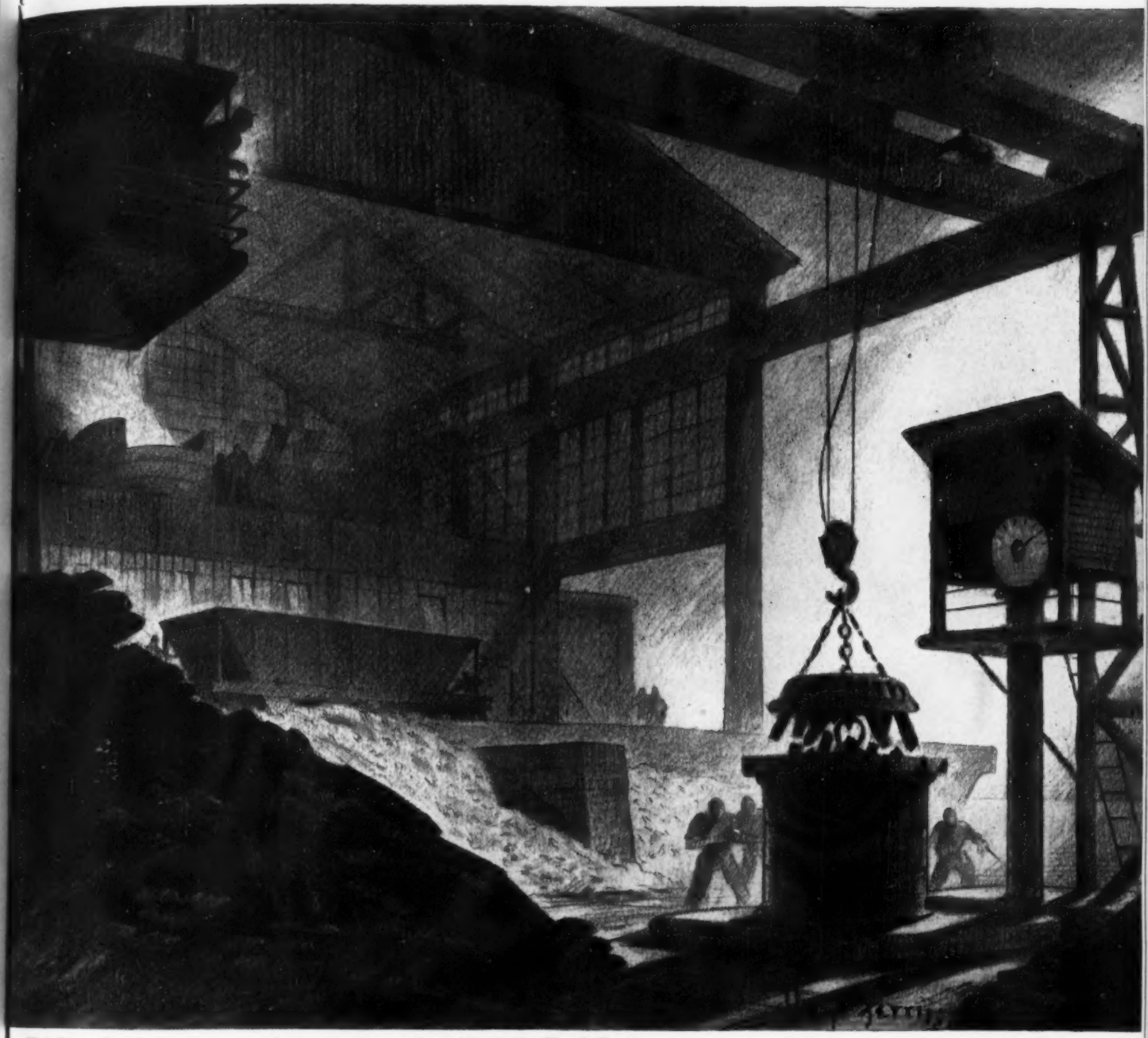
Be sure it is Leadite and not something "Just as Good"

THE LEADITE COMPANY

Girard Trust Company Bldg., Philadelphia, Pa.

No Caulking

From the ground up

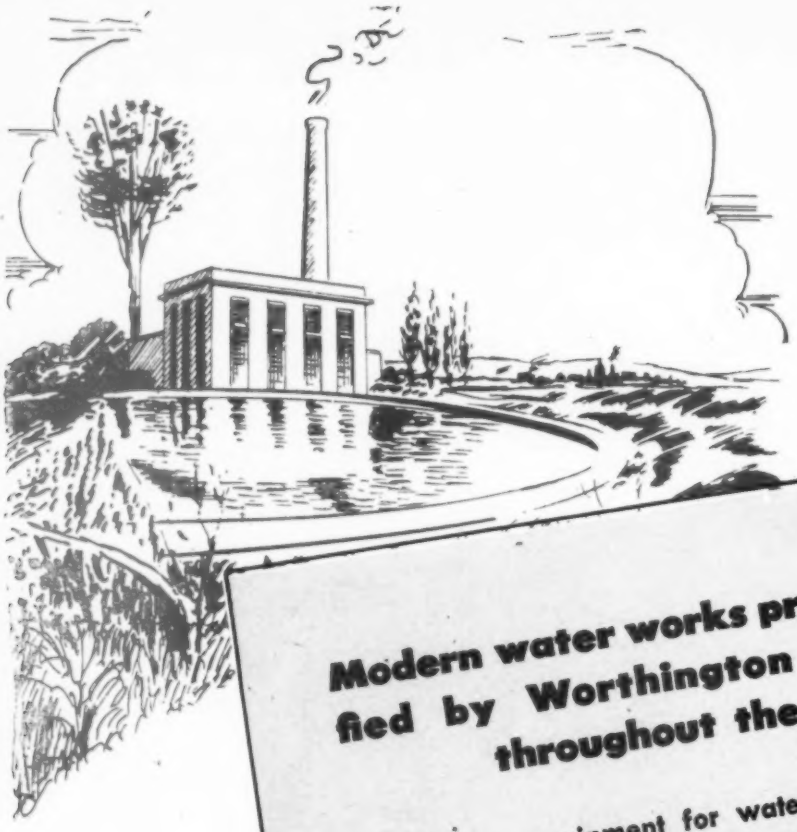


Weighing the charge for a cupola at one of our plants, drawn by Hugh Ferriss.

Few pipe buyers realize the extent of the inspections, analyses and tests involved in our step-by-step control of the quality of Super-de Lavaud Cast Iron Pipe. Production controls *start* almost literally from the ground up with the inspection, analysis and weighing of raw materials—*continue* with the constant control of cupola operation and analysis of the metal from the forehearth; the synchronization of the rotational speed of the mold, travel of the casting machine and pouring rate of the iron entering the mold; the automatic temperature controls of the heat-treating furnaces—and *end* with inspections and a series of acceptance and routine tests of the finished pipe. You can get this pipe promptly if you can obtain the necessary priorities.

UNITED STATES PIPE & FOUNDRY CO.

General Offices: Burlington, New Jersey. *Plants and Sales Offices throughout the U. S. A.*



Modern water works practice is typified by Worthington installations throughout the world

Worthington equipment for water supply comprises a most comprehensive line . . . . not only main units of every type and size, and for every type of drive, but all auxiliary equipment . . . . a complete service with undivided responsibility

CENTRIFUGAL PUMPS
STEAM, POWER AND ROTARY PUMPS
TURBINE WELL PUMPS
DIESEL ENGINES
GAS ENGINES
CONVERTIBLE GAS-DIESEL ENGINES
FEEDWATER HEATERS AND DEAERATORS
AIR COMPRESSORS
PORTABLE COMPRESSORS AND AIR TOOLS
REDUCING AND INCREASING GEARS
MULTI-V-BELT DRIVES
STEAM TURBO-GENERATOR UNITS
MULTI-STAGE STEAM TURBINES
SINGLE-STAGE STEAM TURBINES
COMBINED STEAM TURBINE AND REDUCING GEAR UNITS
STEAM CONDENSERS
STEAM-JET EJECTORS
WATER SOFTENERS
PRESSURE FILTERS
ROCK DRILLING EQUIPMENT
WATER METERS*

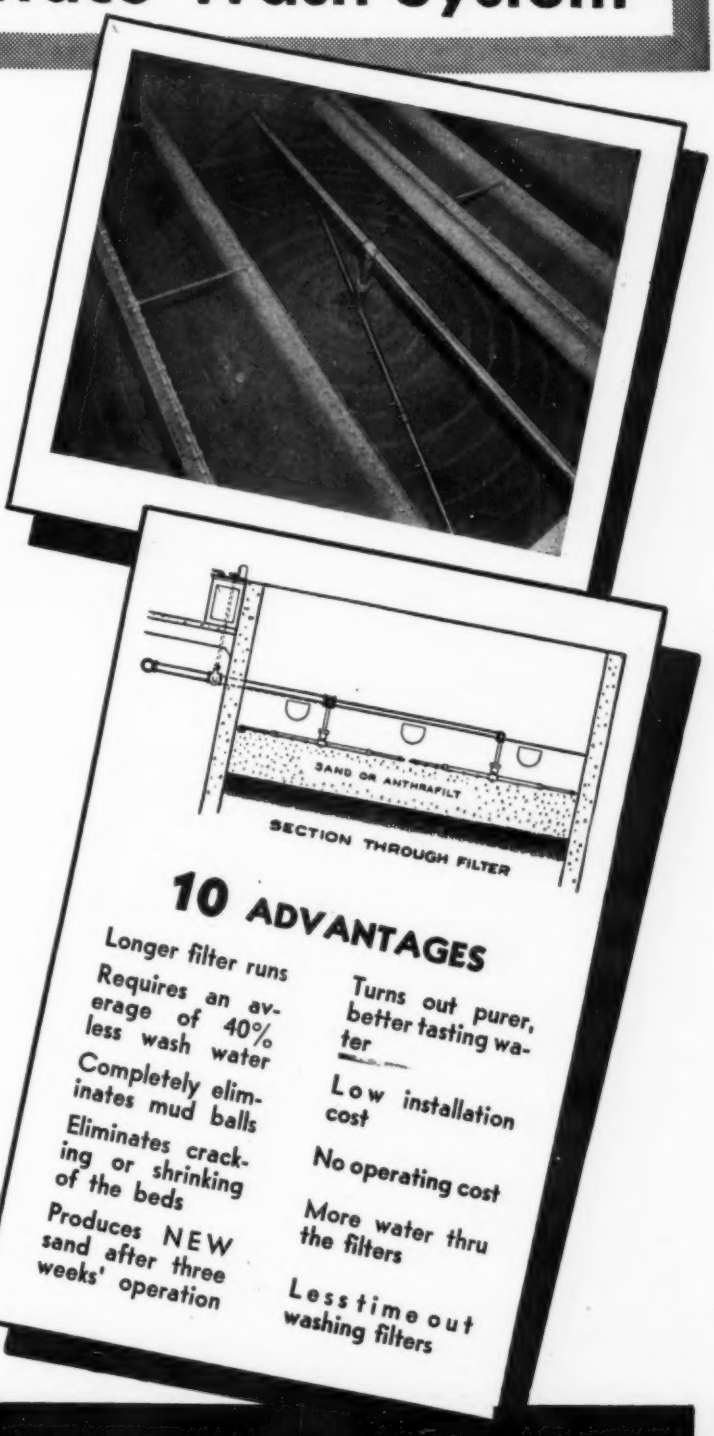
*A complete line of water meters of every type is manufactured by Worthington-Gamon Meter Company, a subsidiary of Worthington Pump and Machinery Corporation

WORTHINGTON

JC3-21

GET MORE WATER THRU YOUR FILTER WITH THE

Palmer Surface Wash System


SAND OR ANTHRAFILT
SECTION THROUGH FILTER
10 ADVANTAGES
Longer filter runs
Requires an average of 40% less wash water
Completely eliminates mud balls
Eliminates cracking or shrinking of the beds
Produces NEW sand after three weeks' operation
Turns out purer, better tasting water
Low installation cost
No operating cost
More water thru the filters
Less time out washing filters

PALMER SURFACE WASH SYSTEMS are now being installed all over the country where the demand for water is exceeding filter capacity.

TYPICAL INSTALLATIONS

WASHINGTON, D. C. (Dalecarlia Plant)—supplying the nation's capital—critical because of "Increased population." (56 Agitators).
(U. S. Engineers)

NORFOLK, VIRGINIA (Moores Bridges Plant)—the "third plant" at Norfolk to install the Palmer Surface Wash System. The demand for water here is a real problem. (36 Agitators).

CAMBRIDGE, OHIO—an "Army Hospital" is putting an extra demand on their system. (8 Agitators).

PORTSMOUTH, VIRGINIA—23 Agitators.
(Defense work in this area tremendous)

LOCKLAND, OHIO—16 Agitators.
Wright Aeronautical Corp.

ELZA, TENNESSEE—16 Agitators.
Stone and Webster designed plant

STUART-BRUMLEY CORP.
516 N. Charles St., Baltimore, Md.

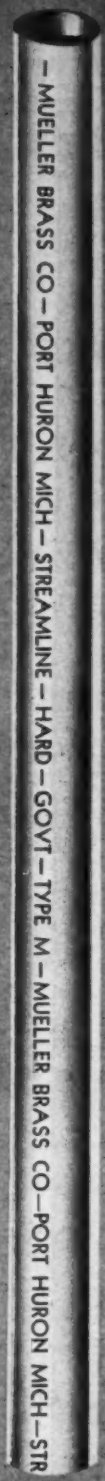
WRITE FOR FOLDER ON OTHER PRODUCTS.

VICTORY FIRST..

We Americans, no matter in what walk of life, realize that armament work must come first. IT MUST TAKE PRECEDENCE OVER EVERYTHING ELSE IF FOR NO OTHER REASON THAN THIS—THAT WE MAY PRESERVE FOR THE FUTURE THOSE VERY BUSINESSES OF WHICH WE ARE NOW TEMPORARILY DEPRIVED. If we fail, everything is lost—our businesses, our freedoms and our democratic way of life.

In a happier yesteryear STREAMLINE copper pipe and bronze solder type fittings were installed in thousands of buildings where a permanently reliable plumbing or heating system was essential. They were used for air conditioning, for water service piping from main to building—for sewage disposal systems and a thousand other uses where dependability and long service life were of prime importance. They were, and still are, universally considered the finest materials that money can buy. TODAY MODERN EQUIPMENT AND MASS PRODUCTION HASTEN STREAMLINE FITTINGS TO OUR ARMED FORCES FOR INSTALLATION IN TANKS AND FIGHTING SHIPS OF ALL KINDS.

When the post-war period dawns, an improved and extended line of STREAMLINE products will have their full share in the rebirth of America, and the world, in the building of better homes for its people.



MUELLER
BRASS CO.
PORT HURON, MICH.

Valves & Hydrants Prompt for delivery to you!

For nearly two years **SMITH VALVES** and **HYDRANTS** have been going into direct war construction. They have become a part of vast Ordnance works, Army and Navy camps, airfields and foreign bases. Today they are helping to build high octane gasoline refineries and synthetic rubber plants.

Because of this urgent war work, our regular customers—the public and private waterworks throughout the country—have been unable to purchase our materials. Now, however, the war construction program is virtually completed and we are once again able to serve the waterworks field with the same SMITH standard of quality and we can do it **PROMPTLY!** Utilities order U-1 provides you with the priority, let SMITH provide you with your Valve and Hydrant requirements.

THE A. P. SMITH MFG. CO. EAST ORANGE, N.J.

Symbol of Quality
Since 1889

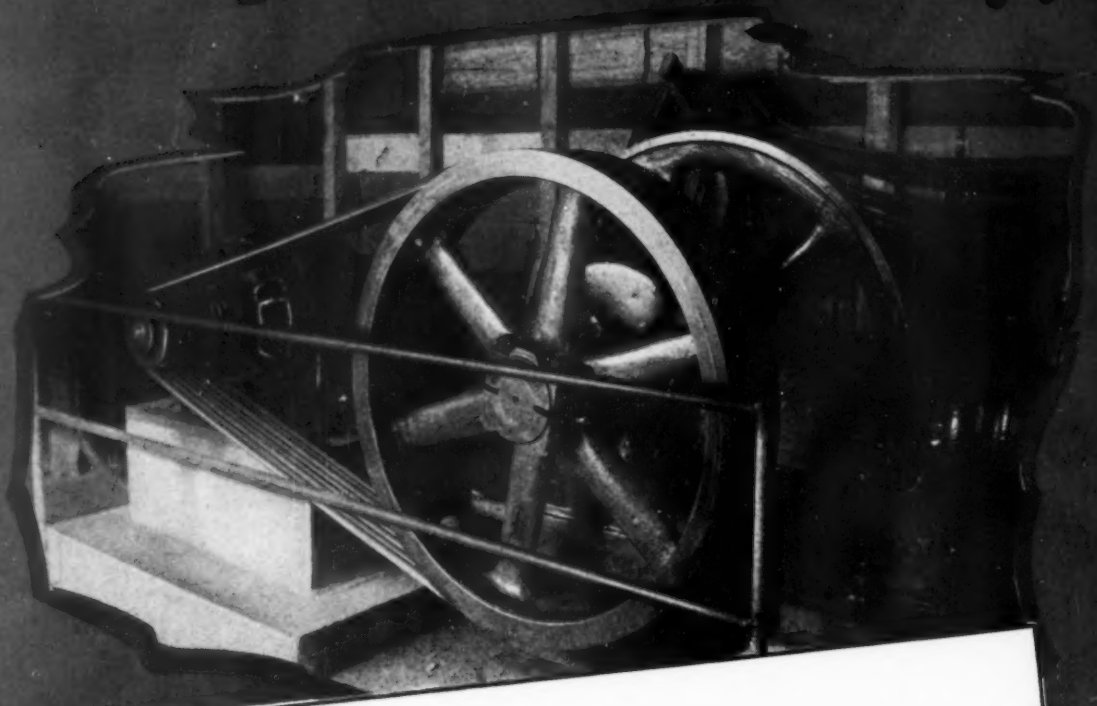
OTHER SMITH PRODUCTS

Smith Tapping Machines
Tapping Sleeves and Valves
Valve Inserting Machines
Pipe Cutting Machines
Repair Sleeves, Check Valves
Removable Plugs—Hat Flanges
Corporation Tapping Machines
Corporation and Curb Cocks
Indicator Posts
Federal Water Meters

THE A. P. SMITH MFG. CO., EAST ORANGE, N. J.

7 So. Dearborn St. Chicago, Ill. | 901 Wm. Oliver Bldg. Atlanta, Ga. | 409 Texas St. El Paso, Texas | 524½ First Ave. South Seattle, Wash. | 59 Oak Vale Ave. Berkeley, Calif. | 315 N. Crescent St. Flandreau, S. D.

24 Hours a day for 24 Years . . .



The VETERAN

This is the Sullivan WG-6 compressor installed in the city of Natchitoches, La. Sept. 17, 1919 and which has served almost continuously since then and is still "operating beautifully".

Form 2325

SULLIVAN MACHINERY COMPANY
INTRACOMPANY CORRESPONDENCE

DATE January 15, 1943

TO R. E. Campbell
OF:
AT Michigan City

(Mark For File)
GENERAL
PRODUCT
DATA

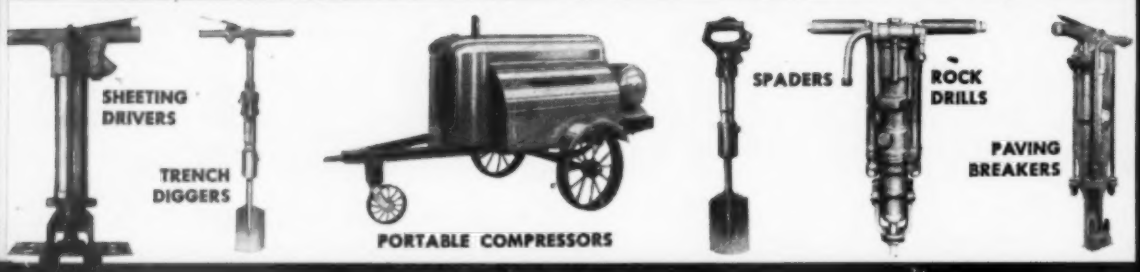
ANSWERING:

Last week I called at the City Water Works at Natchitoches, Louisiana to inspect the new Sullivan WG-9 compressor that was put into service there a couple of months ago. They are all enthusiastically pleased with the initial performance of this WG-9 unit.

While at the plant they insisted that I observe the operation of another Sullivan compressor that they claimed had operated over 200,000 hours. This was the class WG-6 compressor size 11 by 10 shop number 4716 that was shipped on September 17, 1919 and has been operating on practically a 24 hour basis since that date in connection with the pumping of the municipal water supply.

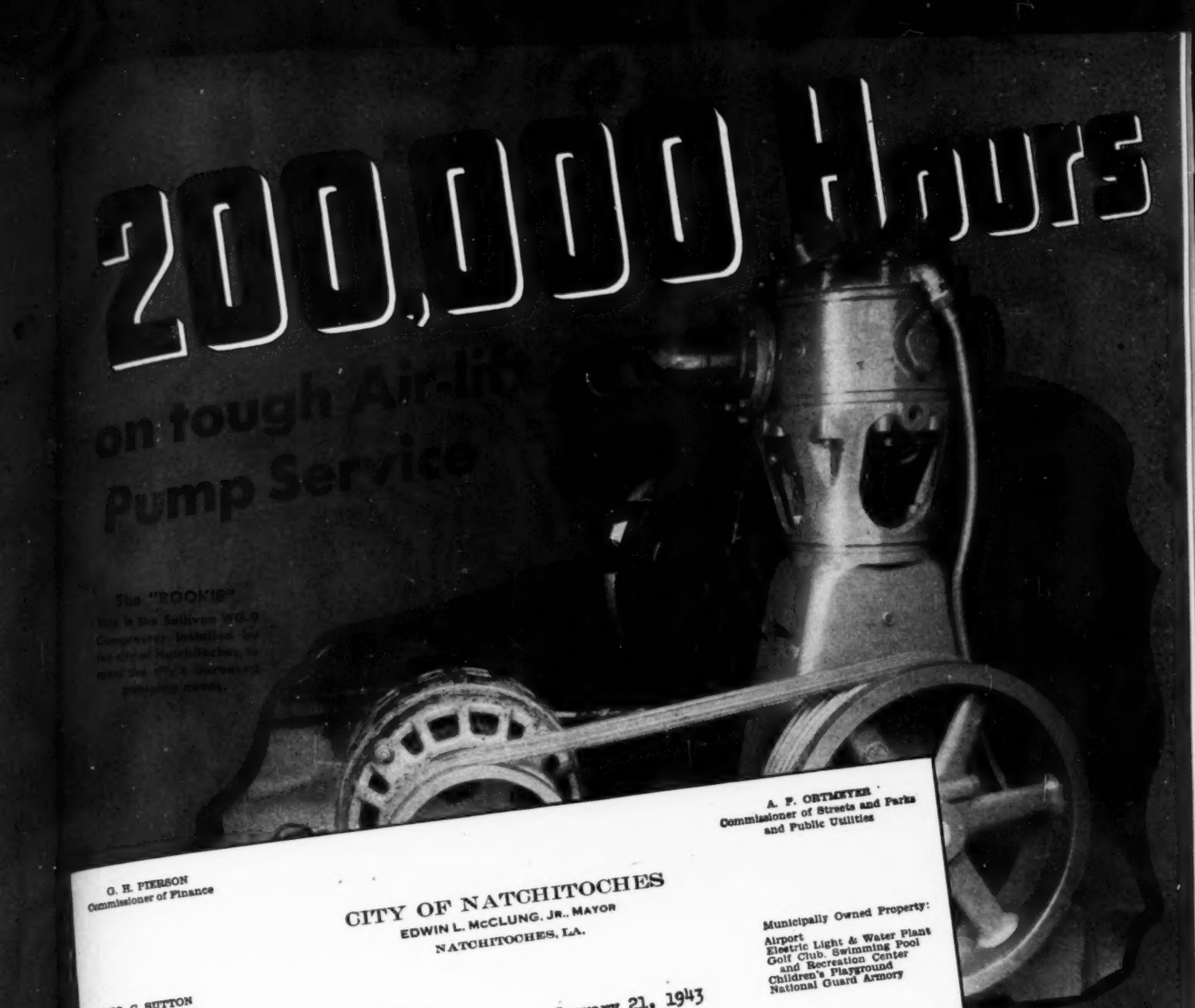
This WG-6 compressor with this 200,000 hours to its credit was operating beautifully and the plant superintendant and the engineer were just as proud of it as they were of the new WG-9 unit.

J. Mayes



200,000 Hours

on tough Air-lift Pump Service



G. H. PIERSON
Commissioner of Finance

A. F. ORTMEYER
Commissioner of Streets and Parks
and Public Utilities

CITY OF NATCHITOCHES
EDWIN L. McCLUNG, JR., MAYOR
NATCHITOCHES, LA.

Municipally Owned Property:
Airport
Electric Light & Water Plant
Golf Club, Swimming Pool
and Recreation Center
Children's Playground
National Guard Armory

GEO. C. SUTTON
Secretary-Treasurer

January 21, 1943

Sullivan Machinery Company
Dallas, Texas

Gentlemen:

We were glad to have you visit the Water Works and see the new Sullivan Class WO-9 Compressor we recently installed to supplement our increased air lift pumping requirements.

The old Sullivan Class WO-6 size 11x10 that we installed in 1919 has operated over 200,000 hours and is still in regular service. During this long period the only replacement parts it has needed are valves and valve parts.

We are counting on the "rooky" giving us as good service as the "veteran".

Yours very truly,
City of Natchitoches,

By S L Perry

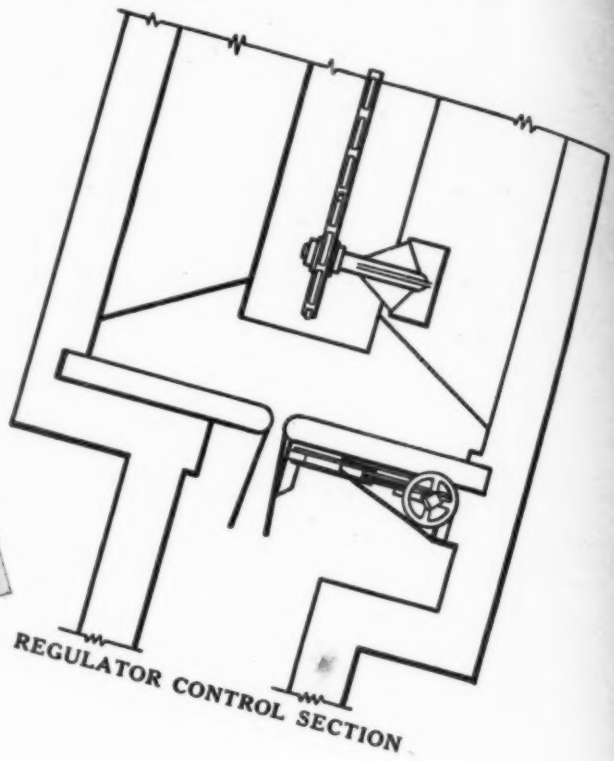
Superintendent

SULLIVAN

AIR COMPRESSORS . . . PORTABLE AND STATIONARY

"American" CAMP REGULATOR

ADJUSTING MECHANISM



REGULATOR CONTROL SECTION

The Camp Regulator is a rectangular control section for accurately CONTROLLING and REGULATING the velocity of flow, over all ranges, through a grit chamber.

The Designer is not required to predetermine the operating grit channel velocity.

The grit chamber may be operated at any velocity proved best by experience for removing grit.

After the velocity has been selected, the Camp Regulator will maintain constant velocity throughout the entire range in flow.

Send for Bulletin No. 249

Be sure to attend the A. W. W. A. Convention, Cleveland, Ohio, June 15 - 18, 1943.

★ ★ ★

Iron Removal Problems? New Release — Bulletin No. 252, Iron and Carbon Dioxide Removal.

Buy American

AMERICAN ESTABLISHED 1868

THE AMERICAN WELL WORKS

AURORA ILLINOIS

MANUFACTURERS OF

Pumping,—Sewage Treatment,—and Water Purification Equipment

Calgon treatment *WORKS*

— in any of these waters!

SCALE prevention and corrosion control *used to be* a merry-go-round of troubles. Solving the scale problem often introduced corrosion —and safety from corrosion could usually be obtained only by forming scale. Now, Calgon *ends* this dilemma — solves four major treatment problems *without causing new ones.*

Soft corrosive water riddles piping and plagues consumers with "red water." Adding alkali to retard corrosion by means of a scale coating usually forms too much scale in lines near the plant and not enough at farther points. Calgon **works** differently. It maintains a thin, protective film over pipe metal and metal oxides throughout the system and reduces the attack of oxygen so effectively that corrosion ceases to be a serious problem and "red water" is eliminated.

"Red water" also results from precipitation of dissolved iron from well water, upon exposure to air, where the dissolved iron exceeds 0.3 ppm. Iron removal equipment is usually not employed unless dissolved iron exceeds 1 ppm., and even then it is not uncommon for "red water" to continue because of corrosion induced by oxygen dissolved in the water during the iron removal process. The best procedure is to add Calgon to well water as it is pumped. This prevents precipitation of dissolved iron and eliminates "red water" and the need for costly removal equipment.

Lime-soda softened water, after filtration, usually contains excess calcium carbonate in solution. Unless this supersaturation can be effectively controlled, scale will form in water lines and hot-water heaters. Effective stabilization, with complete security from corrosion, can best be obtained with Calgon. Added after the softening process, it stabilizes water throughout the system, and eliminates precipitation of calcium carbonate scale in hot-water heaters.

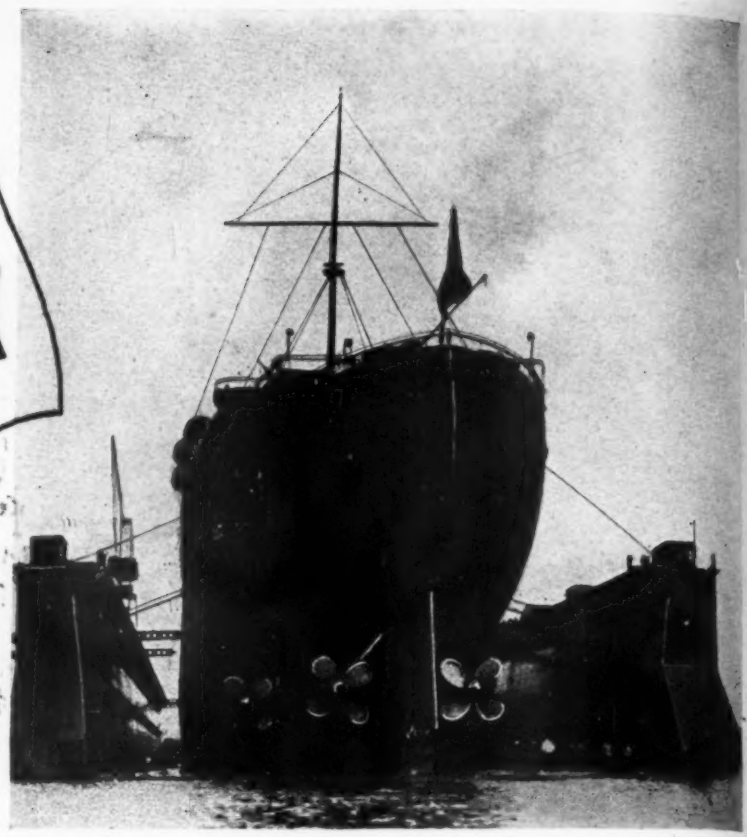
Hard high-bicarbonate water causes scale in consumers' heating coils, tanks and hot-water lines. Calgon offers a simple, economic means of stabilizing water and eliminating scale from home water systems.

These are a few of the specialized applications of Calgon in the water field where the amount of Calgon required is extremely small—from 1 to 5 ppm., depending upon individual plant conditions. Write for complete information and a sample for making your own tests.

**Calgon is the registered trade-mark of Calgon, Inc. for its vitreous sodium phosphate products.*

calgon, inc.

HAGAN BUILDING PITTSBURGH, PA.



RENSSELAER VALVES *Vital in Our largest Modern Drydocks*

The present conflict has aptly been called a "war of engineers." Here, we believe, is one of the best examples of "engineered" valve installations. RENSSELAER has supplied many hundreds of large valves and operating assemblies for Floating Dry Docks.

For installations requiring the UTMOST IN DEPENDABILITY, engineers specify RENSSELAER.

★

Write for Bulletin X

RENSSELAER VALVE CO., TROY, N. Y.

BRANCH OFFICES

ATLANTA, GA., Rhodes-Haverty Building
CHICAGO, ILL., Monadnock Building
DALLAS, TEXAS, Allen Building
HAVERHILL, MASS., Coombs Building
LOS ANGELES, CAL., Subway Terminal Building
PITTSBURGH, PA., Oliver Building
SAN FRANCISCO, CAL., Sharon Building
SEATTLE, WASH., 2726First Avenue, South

DIRECT REPRESENTATIVES

HEMPSTEAD, N. Y., 62 Patterson Avenue (Mr. J. E. Williamson)
PHILADELPHIA, PA. 14 Rockhill Rd., Bala-Cynwyd (Mr. R. W. Turner)
ROCHESTER, N. Y., 131 Hurstbourne Road (Mr. J. S. Ten Eyck)
OKLAHOMA CITY, OKLA., Braniff Building (Mr. E. J. Connelly)

FOR OVER 50 YEARS

*Sincerely yours**

HAS BEEN PROUDLY INSCRIBED—IN EFFECT IF NOT IN FACT—
ON THOUSANDS OF BUILDERS FLOW METERS AND CONTROLLERS

50 YEARS' EXPERIENCE
in the Design and Manufacture of
Water and Sewage Works Equipment

AT YOUR SERVICE
for
POST WAR PLANNING

VENTURI METERS
TYPE M. FLOW WATCH AND CHRONOFLO METERS
VENTURI CONTROLLERS · FILTER GAUGES
LIQUID LEVEL GAUGES · RATIO GAUGES · KENNISON NOZZLES
CHRONOFLO TELEMETERS & CONTROLLERS
TOLEDO CHRONOFLO CONVEYOR WEIGH METERS
Correspondence Invited

* Back in the old days, second-rate Roman sculptors who made unsightly nicks in the marble would secretly patch up the flaws with a mixture of wax and marble dust. These patches would drop out later on and honest artists suffered so much that they began labelling their handiwork "Sine Cera" (i.e. "without Wax"); from this we derive our word "sincere" meaning honest, genuine, real.

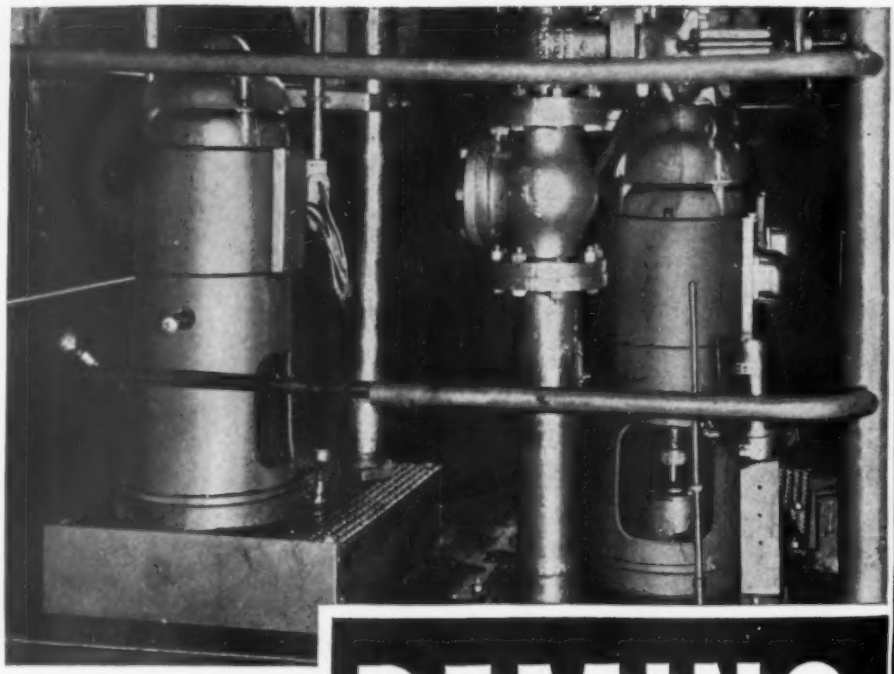
ARMY E NAVY
AWARDED
AUG. 1 st 1942

BUILDERS-PROVIDENCE, INC.

Est. 1820 • DIVISION OF BUILDERS IRON FOUNDRY • Inc. 1852

9 CODDING STREET • PROVIDENCE, R. I.

BUILDERS
RECORDING-INDICATING-CONTROLLING
Instruments



DEMING PUMPS

VERTICAL SUMP PUMPS

Installed in pits of every description for sump drainage. Also used for screened sewage. Capacities from 10 to 320 g.p.m. against heads up to 120 feet. Speeds from 860 to 1750 r.p.m. for motor drive. Ask for Bulletin 4603.

DEEP WELL TURBINE PUMPS

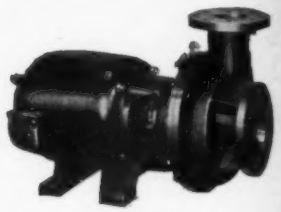
For deep well water supply at low cost. Capacities range from 15 g.p.m. to 3000 g.p.m. Bearings lubricated by water from well, eliminating contamination of water supply by lubricating oil or grease as none is required below pump head proper. Bulletin 4700-8 gives full details about these modern pumping units.

Illustrated on this page are representative examples of various types of Deming Pumps used extensively in municipal and industrial water works and sewerage systems.

Wide diversification of types and capacities of Deming Pumps provides you with an exceptional range of selection to meet many specifications with standard equipment.

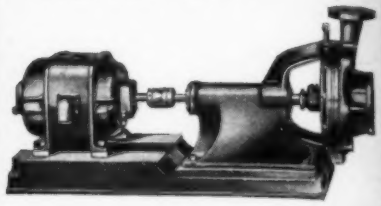
Technical catalogs and bulletins are available to assist you in determining the best type and capacity of Deming Pumps for each indicated requirement.

A nationwide network of Deming Distributors makes it possible to offer you prompt sales and service cooperation regardless of your locality. For further particulars, address The Deming Company, Salem, Ohio.



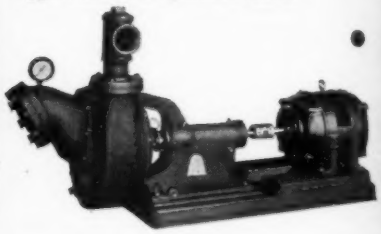
"MOTOR MOUNT" CENTRIFUGAL PUMPS

Compact, dependable, high efficiency, low cost units. Available in 63 sizes. Capacities range from 5 to 650 g.p.m. Complete details, specifications, and key to selection chart included in Bulletin 4301. Ask for it.



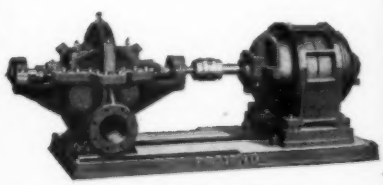
SIDE SUCTION CENTRIFUGAL PUMPS

These pumps can be furnished for belt, electrical motor, or gasoline engine drive. Sizes range from 1 to 10 inches with capacities from 10 to 3600 g.p.m. Single ball bearing and two ball bearing types. Ask for Bulletin 4200.



SELF-PRIMING CENTRIFUGAL PUMPS

Equipped with float switch control for sump service. Priming operations completely automatic. Semi-enclosed, non-clogging impeller. Pumps can be furnished direct connected through flexible couplings to electric motors or gasoline engines, or with pulley for belt drive. Capacities from 600 to 18,000 gallons per hour. Ask for Bulletin 3000.

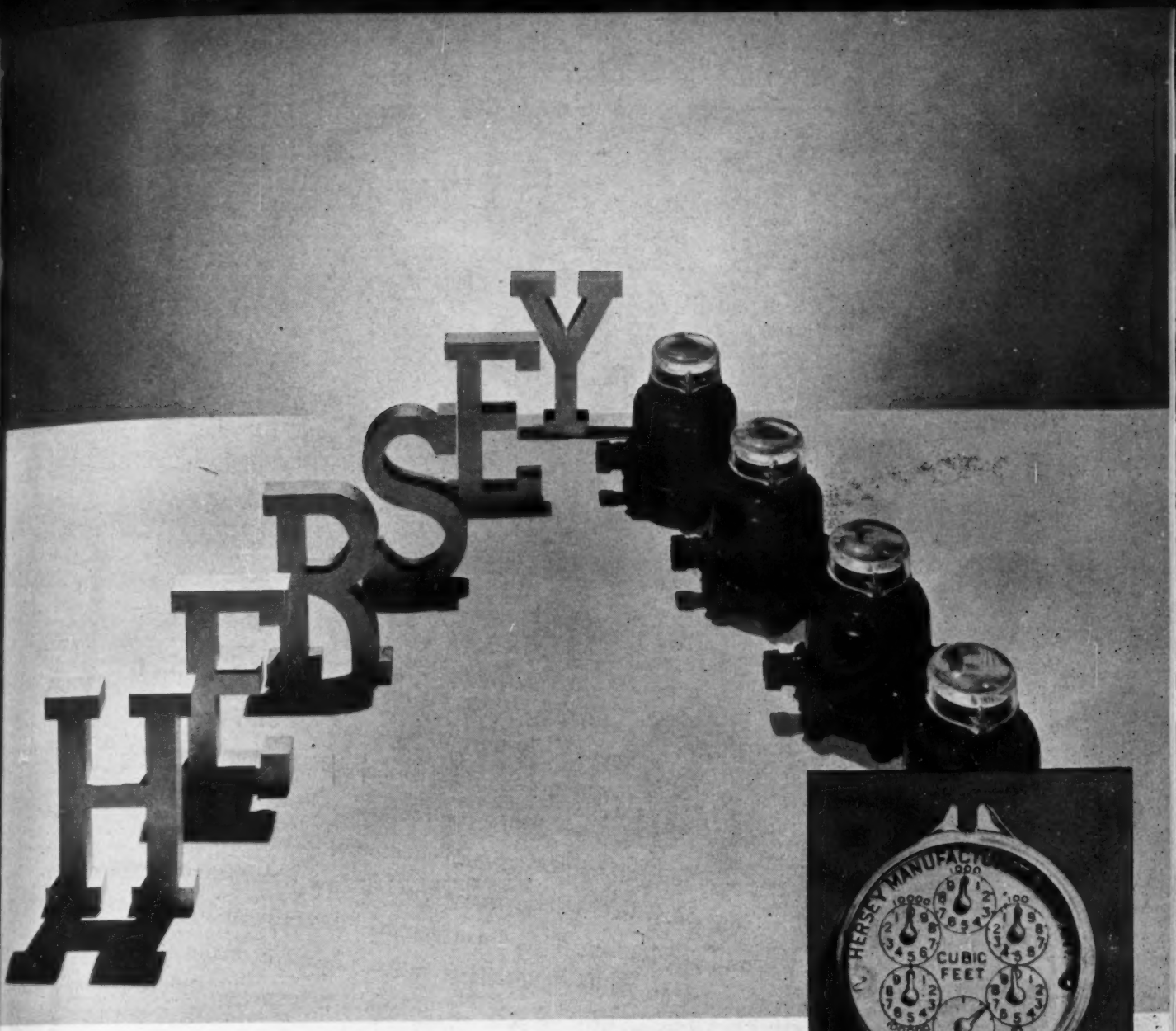


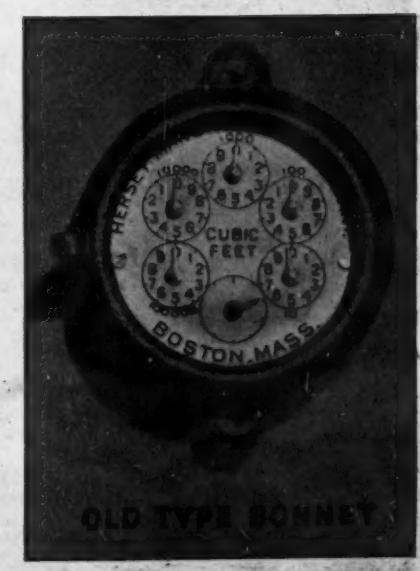
DOUBLE SUCTION CENTRIFUGAL PUMPS

Horizontally split casing. Recommended for working pressures up to 200 pounds. Rotating elements in perfect static and dynamic balance. Vibrationless at all speeds. Sizes 1½ to 10 inches. Capacities up to 5000 g.p.m. at heads up to 350 feet. Ask for Bulletin 5003.

THE DEMING COMPANY

SALEM • • • OHIO





HERSEY IRON CASE WATER METERS

have been approved by water works officials everywhere. The real feature that has won their universal approbation is the new Magni-Vision* All Glass Bonnet.

The results of this improvement are greater illumination and magnification of the face of the dial and faster and more accurate reading.

A special circular describing this feature will be mailed upon request.

HERSEY MANUFACTURING COMPANY

SOUTH BOSTON, MASS.

BRANCH OFFICES: NEW YORK — PORTLAND, ORE. — PHILADELPHIA — ATLANTA — DALLAS
CHICAGO — SAN FRANCISCO — LOS ANGELES

*Patented by a Hersey engineer June 4, 1907

No Gold Braid, but . . .

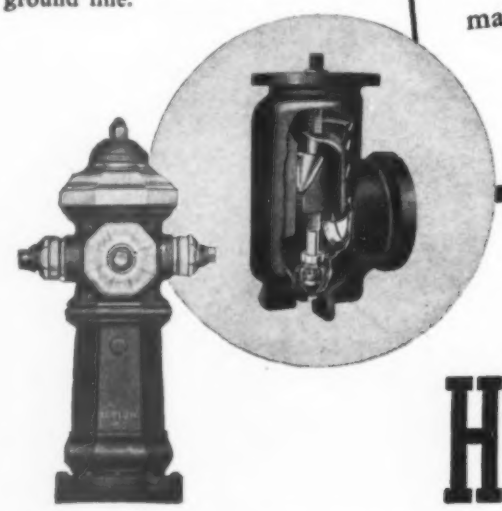
. . . the earnest men who direct and maintain vital municipal waterworks and sewerage systems have their strategical problems, too. They must conduct their campaigns against fire, flood and epidemics—all enemies of industry and public welfare which would interrupt or slow down manpower and production. They must marshall carefully such supplies as are available. They must shift equipment, make repairs and use to the utmost advantage whatever is obtainable under priority restrictions.

Ludlow, regardless of a sincere wish to be co-operative, is limited by rulings of the War Production Board. We will gladly send you such information as we have on WPB priorities and, when you have obtained a rating, we will make shipment with all possible promptness.

V-6

THE LUDLOW VALVE MFG. CO., INC.
TROY, NEW YORK

LUDLOW HYDRANT CONSTRUCTION: Self-releasing 30° angle wedges and free-floating gates, self-adjusting to seats, afford smooth, trouble-free performance, long service. Opening and closing of hydrant automatically opens and closes drain, located at lowest point. Clogging is prevented. Gate is wedge-locked when closed, to prevent flooding. All working parts may be lifted through top of hydrant for easy inspection. Top and bottom bodies bolted together at ground line.



LUDLOW
HYDRANTS AND VALVES
SINCE 1866

BRONZE METER CASES HAVE GONE TO WAR

Yes! We continue to manufacture Water Meters, with Army, Navy and Maritime Commission taking preference.

Of course, we are operating under WPB Limitation Order L-154 to conserve copper, and must use substitutions for certain critical materials. That is why Worthington-Gamon Household Meters now come to you with iron casings and glass register boxes.

However the Limitation Order does not affect the interior parts. Therefore the materials in the gear train and measuring chamber remain unchanged.

Accuracy is assured by maintaining the same rigid manufacturing standards as in the past . . . and all parts are interchangeable with your other Worthington-Gamon Meters.

WATCH DOG

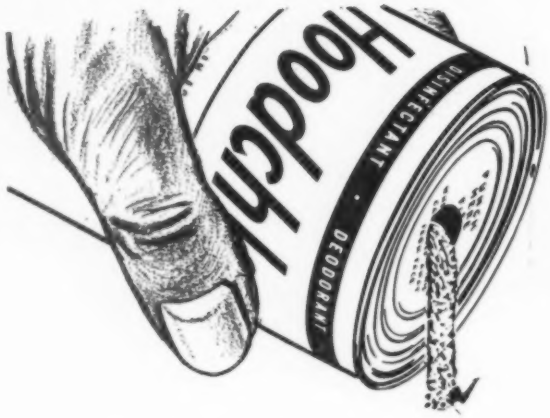
WATER METERS

WORTHINGTON-GAMON METER COMPANY
282-296 SOUTH STREET NEWARK, NEW JERSEY

WG3-3

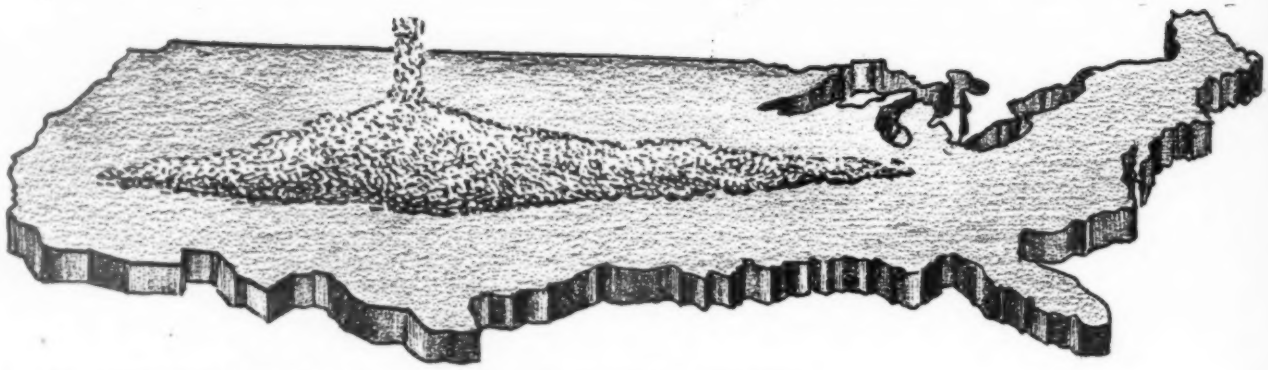
WORTHINGTON-GAMON

KEEP THE HOME FRONT HEALTHY TOO



HIGH TEST HYPOCHLORITE 70% Available Chlorine in Stable, Convenient Granular Form

HOODCHLOR



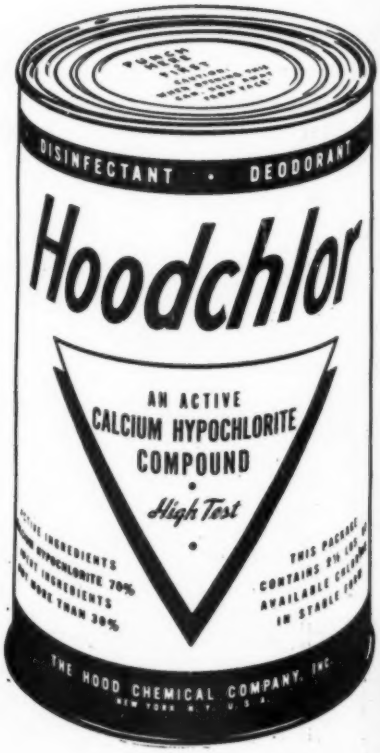
Although most HOODCHLOR is allocated each month to safeguard our armed forces from water pollution, HOOD'S production facilities make possible a limited supply for civilian protection.

HOODCHLOR provides the sure and simple way to protect communities, institutions, and private groups from contaminated drinking water. Municipalities and all other consumers in this field should keep a supply on hand for emergency use. There's no better, cheaper form of health insurance.

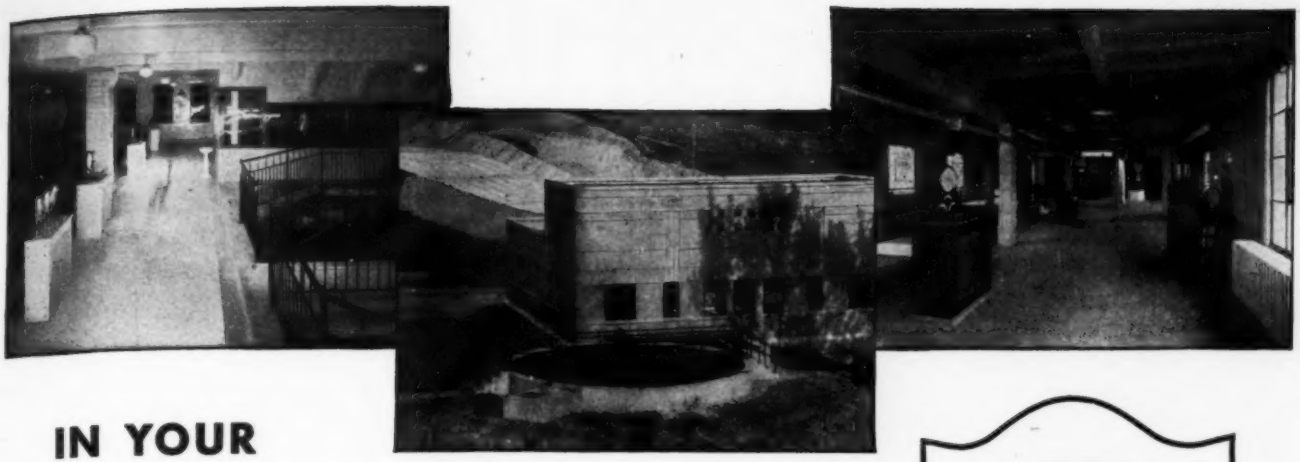
HOODCHLOR is also highly recommended for sewage disposal plants, for sterilizing new water mains and swimming pool water.

HOODCHLOR is a high-test calcium hypochlorite, containing 70% available chlorine. It is a dry, free flowing white granular material, readily soluble. It will keep your water up to the highest standard of purity demanded by any local or State Board of Health.

HOODCHLOR is packed:
12 3¾-lb. cans to the case.
9 5-lb. cans to the case.
100-lb. drums (when available).



HOOD CHEMICAL CO., Inc.
Executive Offices: 450 West 31st Street, New York, N.Y.
Factory: Akron, Ohio
HOODCHLOR HIGH TEST CALCIUM HYPOCHLORITE · CAUSTIC SODA
BICARBONATE OF SODA · SODA ASH · CHLORIDE OF LIME



IN YOUR POST WAR PLANNING

Remember—

The INFILCO Equipped Water Purification Plant CENTRALIZES EQUIPMENT RESPONSIBILITY AND ASSURES COORDINATED RESULTS

You are invited to make use of the experience gained by Infilco during the 40-odd years of designing and manufacturing every type and size of water purification equipment.

In furnishing everything required for water conditioning—from Accelators to Zeolites—Infilco offers you the important advantage of undivided responsibility for successful equipment operation.

And—your plant will be in step with modern developments, because Infilco has always been the first to introduce and adopt worthwhile improvements, as well as first to discard anything proving to be a hindrance to progress.

The services of its staff of experienced engineers and laboratory facilities are at your disposal for the asking.

INFILCO
INCORPORATED
325 W. 25TH PLACE • CHICAGO, ILL.

INFILCO

PRODUCTS

- Accelators
- Aerators
- Automatic Controls
- Chemical Feeders
- Clarifiers
- Coagulators
- Digesters
- Dosing Siphons
- Filter Equipment
- Flow Controllers
- Flow Gauges
- Fluorex Purifiers
- Gravity Filters
- Hydraulic Controls
- Hydraulic Switches
- Hydrodarco Purifiers
- Level Controls
- Lime Slakers
- Loss of Head Gauges
- Mixing Equipment
- Pressure Filters
- Proportioners
- Recarbonators
- Rotary Distributors
- Samplers
- Settlers
- Sewage Activators
- Sewage Equipment
- Sewage Griductors
- Venturi Tubes
- Wagner Underdrains
- Water Filters
- Water Softeners
- Zeolites

Moving Up with the Engineers

Photo by U.S. Army Signal Corps

THERE is no "front line" for the U. S. Army Engineers. With their bridges, assault boats, mines, and explosives, they fight on every front and in front of the front.

With their tools and equipment they are at the ports and behind the ports. In between, they are everywhere, constructing air fields, building roads, laying pipe lines, installing water systems, running railroads—doing anything and everything to "aid the movement of our own troops and to impede the enemy."

On the move with the Engineer Corps, following the Men of the Castle around the world, are Dresser Pipe Couplings and Repair Clamps. From camps and cantonments at home to far-flung island bases, from Alaska to Africa, from Iceland to the Caribbean—wherever pipe lines must be built fast or repaired quickly—there the speed and simplicity of Dresser products are recognized and utilized.

The familiar Castle, insignia of the U. S. Engineer Corps, is said to have been introduced by the Marquis des Androuins, one of the French engineers brought to this country by General George Washington. des Androuins based his design on the castle which guarded the gates of Verdun.

The Corps of Engineers is the only branch to have a distinctive uniform button of its own, featuring a castle which legend says is a likeness of the first fortification built on Governor's Island, New York Harbor.

Dresser Manufacturing Co., Bradford, Pa.

DRESSER

Pipe Couplings, Repair Clamps, Rings, Wheels, and Forgings for War

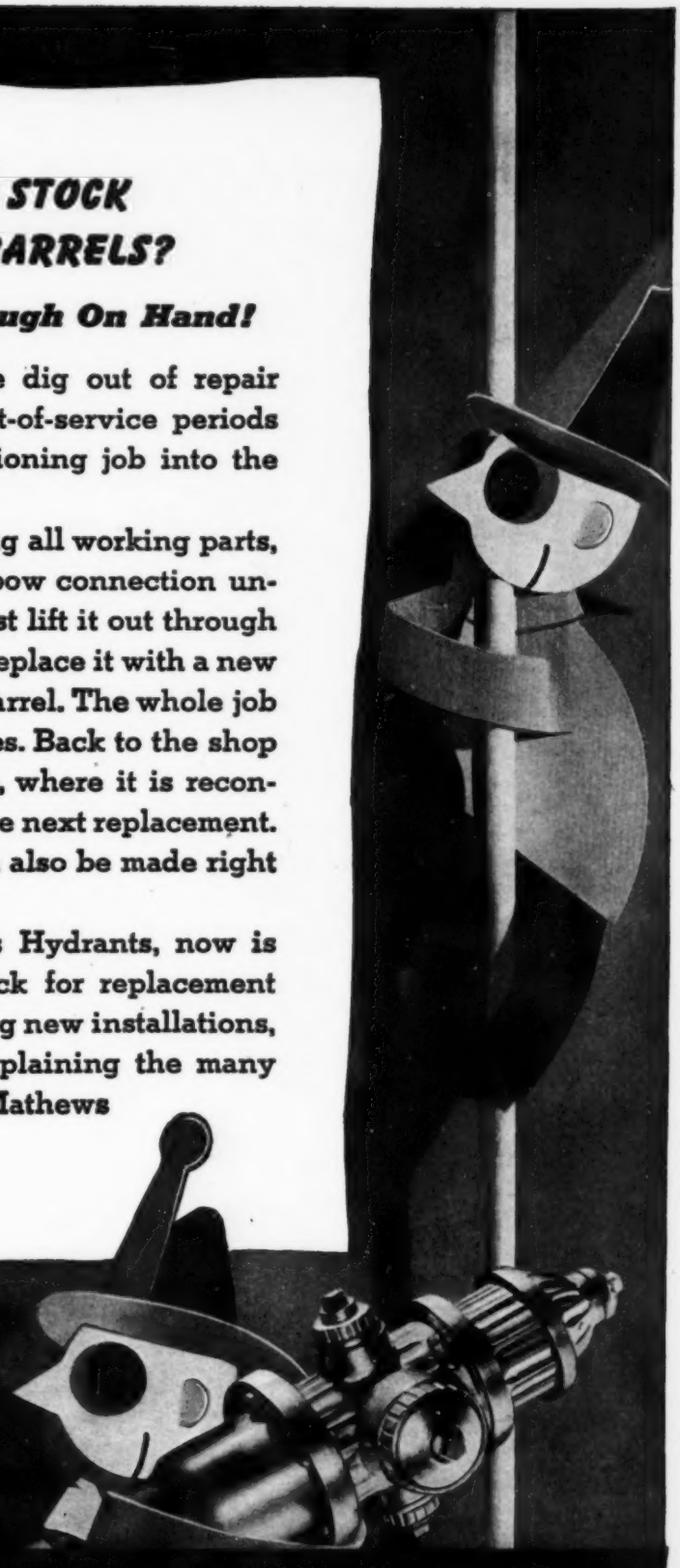
HOW'S YOUR STOCK OF MATHEWS BARRELS?

It Pays To Keep Enough On Hand!

Mathews Hydrants take the dig out of repair work . . . eliminate long out-of-service periods . . . and bring the reconditioning job into the shop, where it belongs.

The entire barrel, including all working parts, *easily* unscrews from the elbow connection under the ground. Then you just lift it out through a loose protection case and replace it with a new or reconditioned Mathews Barrel. The whole job takes only a matter of minutes. Back to the shop goes the barrel you took out, where it is reconditioned at your leisure for the next replacement. (Of course, minor repairs can also be made right on the job.)

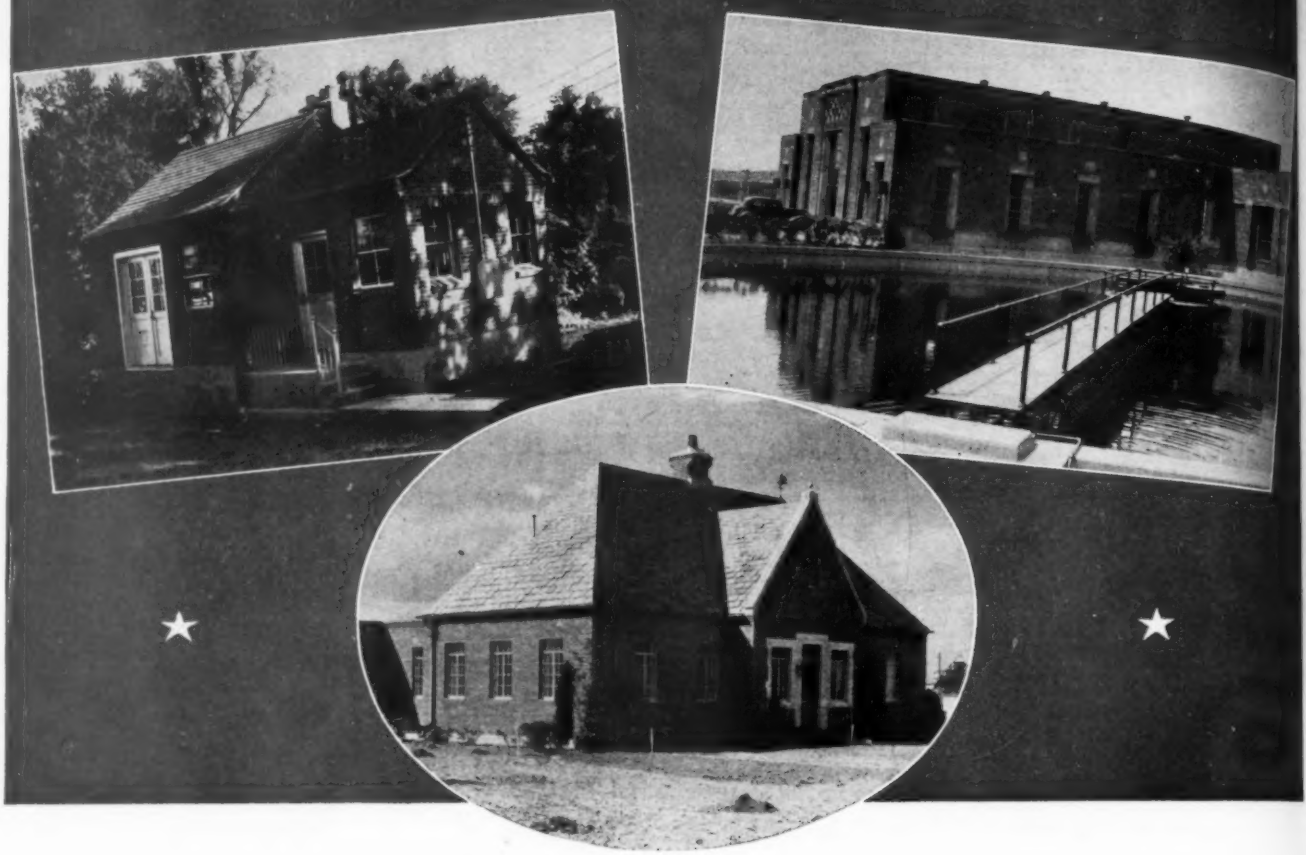
If you are using Mathews Hydrants, now is the time to check your stock for replacement barrels. If you are considering new installations, send for special booklet explaining the many worthwhile advantages of Mathews Hydrants.



Made by R.D. WOOD Company

Big plant or Small,

ALUMINUM IS MAKING MAINTENANCE EASIER



Aluminum windows and doors, installed before aluminum went to war, grace all of these buildings; the little isolated pumping station, the small town and big city disposal plants. And elsewhere throughout these buildings, aluminum is contributing to their fine appearance and lower upkeep costs.

In these days when manpower for maintaining sewage treatment plants is at a premium, operators are valuing their aluminum fittings and equipment more than ever. Where used for decorative purposes, it is easy to keep bright and shining. Where it was installed primarily as a barrier against corrosion, it goes about that job with a minimum of attention.

Decorative aluminum, handrails, window sills, light reflectors and instrument housings usually have an Alumilite finish*. They need only an occasional dusting off or washing with mild soap and water. Aluminum window frames, skylights, coping, spandrels, air ducts, and the like, should be cleaned periodically. This prevents the accumulation of moisture-holding pockets of dirt which might cause trouble.

Alcoa engineers will gladly help you decide on ways of assuring maximum life for irreplaceable aluminum alloys in your plant. ALUMINUM COMPANY OF AMERICA, 1955 Gulf Building, Pittsburgh, Pennsylvania.

*Process patented

ALCOA ALUMINUM

Lock Joint Pipelines Speed Work on Synthetic Rubber Plants

SYNTHETIC RUBBER is vital to the war effort ... and water supply is vital to the production of synthetic rubber.

Reinforced Concrete Pressure Pipe is supplying the immediate need for pipelines, and by being "tailor-made" to fit the job, is conserving thousands of tons of steel urgently needed for the production of armaments.

Probably in no other type of work are there so many special fittings, elbows, tees or wyes required as in the pipelines serving synthetic rubber plants—yet each one of these can be quickly and readily supplied in standard Lock Joint designs.

◆ ◆ ◆ ◆

Whether your project is large or small, your 'phone call, telegram, cable or letter to any of our offices will bring a prompt reply.

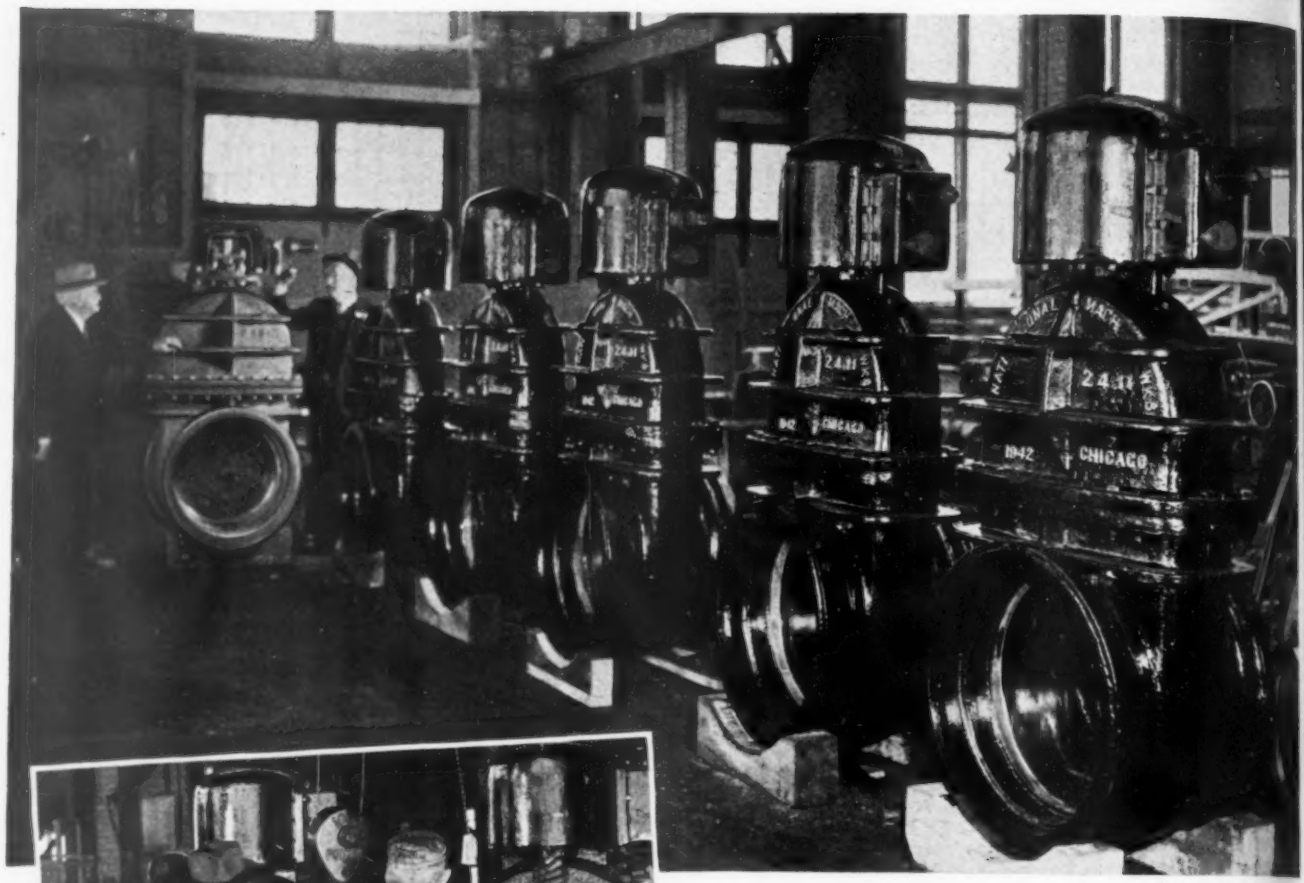
LOCK JOINT PIPE COMPANY
Established 1905
AMPERE, NEW JERSEY

Denver, Colo. • Chicago, Ill. • Kenilworth, N. J. • Kansas City, Mo. • Rock Island, Ill.
White Plains, N. Y. • Valley Park, Mo. • Cleveland, Ohio • Hartford, Conn. • Navarre, Ohio

SCOPE OF SERVICES *Lock Joint Pipe Company specializes in the manufacture and installation of Reinforced Concrete Pressure Pipe for Water Supply Mains as well as Concrete Pipe of all types for Sanitary Sewers, Storm Drains, Culverts and Subaqueous lines.*

LOCK JOINT
Reinforced Concrete
PRESSURE PIPE

TWENTY 24'S FOR THE CITY OF CHICAGO



While a city engineer looks on, a National shopman lowers a bronze-fitted disc into a 24" valve. Basically good design, plus expert workmanship, assures easy opening and tight closure of the valve—no binding. Also illustrated above is a smaller type of National Gate Valve.

Part of a shipment of Gate Valves designed for water main service

Selection of equipment for the water mains of a huge metropolitan area is a job calling for experienced judgment. Any unit not completely dependable is a potential menace to both public health and the essential activities of city life.

The above group of Gate Valves is evidence of a critical engineering staff's approval . . . twenty-four inchers, chosen for use in a great city's vital water service. Under their massive construction is the precision workmanship which means smooth, trouble-free operation.

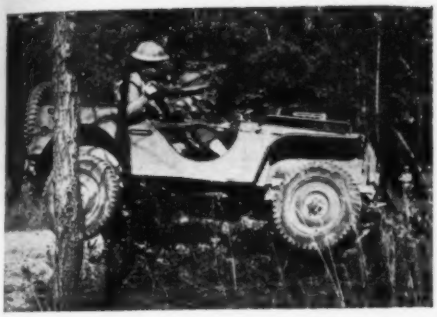
Whatever size or type of gate valve you need, you'll find a complete selection at National . . . from knee-high units to giants twice a man's height . . . either manually or power operated. If standard designs won't suit, we'll build to your specifications.

Estimates and engineering counsel cheerfully given—write for full information.

NATIONAL
MACHINE WORKS

1559 North Sheffield Ave. Chicago, Ill.

WAR PRODUCTION *Comes First!*

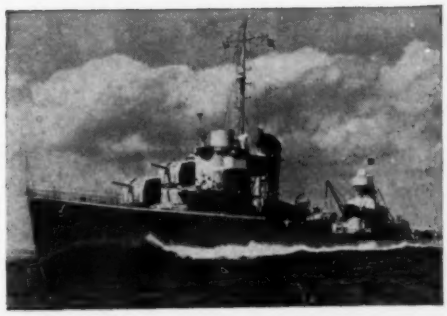


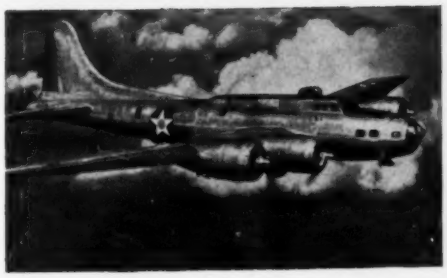
The Silicate demands of our war industries of course deserve and receive first consideration today.

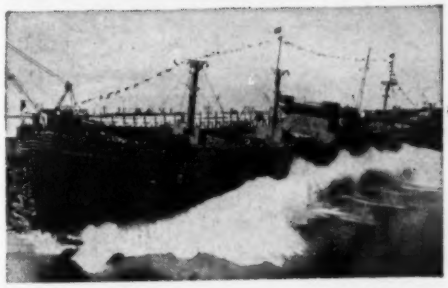
YOU can help the manufacturer and yourself by anticipating your Silicate requirements as far in advance as possible.

Won't you Cooperate?

ALKALI



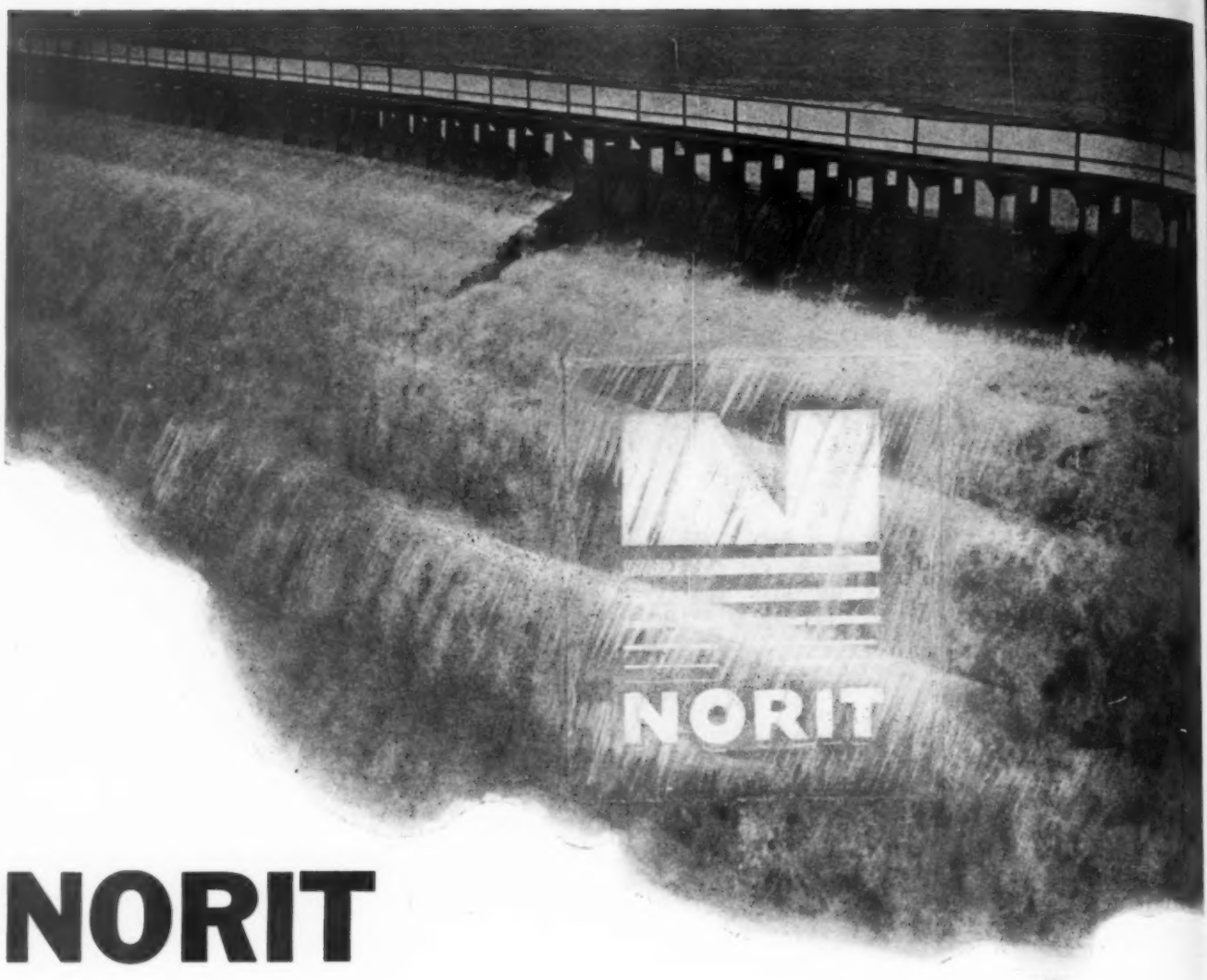




DIAMOND ALKALI COMPANY • Standard Silicate Division

Plants at CINCINNATI · JERSEY CITY · LOCKPORT, N. Y.
MARSEILLES, ILLINOIS · DALLAS, TEXAS

General Offices · PITTSBURGH, PA.



NORIT

the most potent enemy of odors and tastes in Water Supplies

The absorbing properties of NORIT are exceptionally good. A little goes a long way . . . one of the reasons why it is used in a number of leading cities to rid drinking water of disagreeable odors and tastes.

There are two types of NORIT—an activated carbon processed from pure charcoal with steam: Powdered with a guaranteed phenol value of 14 or better and Granulated with a guaranteed phenol number of not less than 9.

If you are not familiar with the research work done by NORIT Technicians and with NORIT itself, send for our catalog.

PRODUCED BY

AMERICAN NORIT COMPANY, INC.

Jacksonville, Florida

Distributed by **L. A. SALOMON & BRO., 216 Pearl Street, New York, N. Y.**

Plangineering—Something to DO NOW to Avoid Slack at War's End

"PLANGINEERING" is not just *talking* about post-war projects. It is doing something about them NOW!

Now? With the manpower shortage and with *permanent* high-grade materials and equipment so hard to get even on priority?

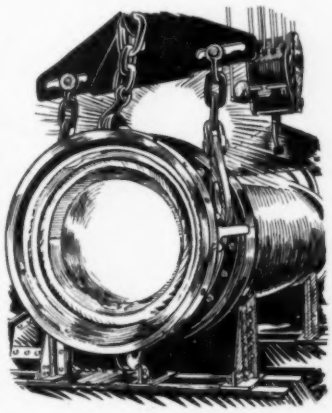
Yes, NOW! Many a water works, sewerage, gas and pipe-line system will need re-vamping after the war. Why waste valuable months when with "plangineering" you can be ready to start necessary work almost immediately at war's end?

How? *Plangineer* — write down a list of the things you would do on your system within the next year if the war ended this month. Turn it over to one of your remaining technical men or a consulting engineer and instruct him:

(1) To work up a skeleton set of plans and specifications.

(2) To prepare a bill of materials, paying particular attention to the elimination of war-time "makeshifts", and their replacement with materials of time-tested permanency—corrosion resisting cast iron pipe, for instance, now made in accordance with the recently adopted A.S.A. LAW OF DESIGN.*

(3) To estimate the cost, based on the 1940 level (or some other year). This will give a *base* estimate readily adjusted up or down percentagewise with sufficient accuracy to approximate material and labor costs current after the war. This will give a base for promptly discussing and arranging financing if necessary.



(4) Review the list at six-month intervals, and revise plans, specifications and estimate accordingly.

PLANGINEER NOW to insure a quick start on needed improvements and conversions immediately the war ends. Our soldiers need not be out of jobs when they return home if enough of us do "plangineering".

*We will gladly send you a copy of the American Standards Association LAW OF DESIGN FOR CAST IRON PIPE. By following the A.S.A. LAW OF DESIGN, weights and thicknesses of cast iron pipe can be scientifically designed for specific laying conditions. No more guessing when writing specifications. You get the *exact* pipe your conditions call for. Economy with safety is the result. Long life with low maintenance, too.

AMERICAN CAST IRON PIPE COMPANY

BIRMINGHAM, ALABAMA

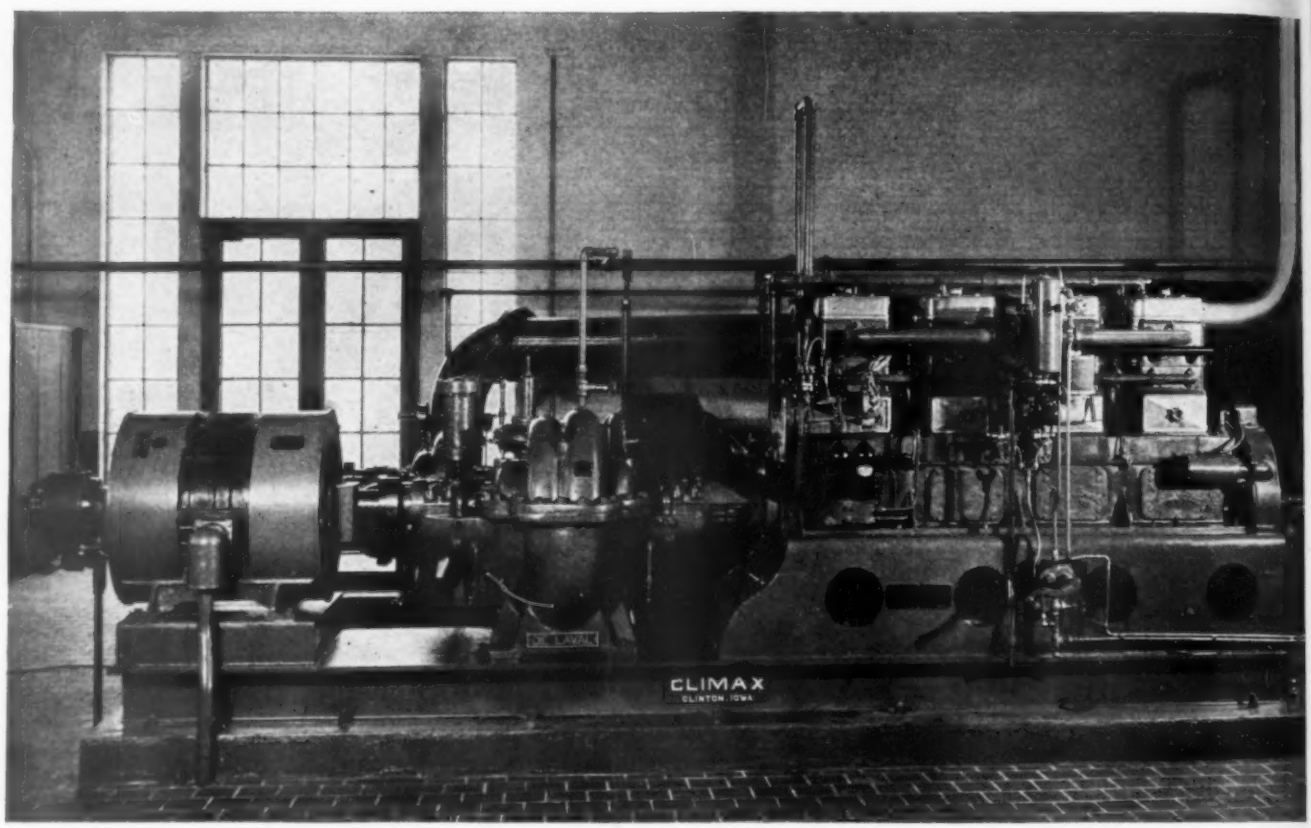
Sales Offices in Chicago, Cleveland, Dallas, Houston, Kansas City, Los Angeles, Minneapolis, New York, San Francisco

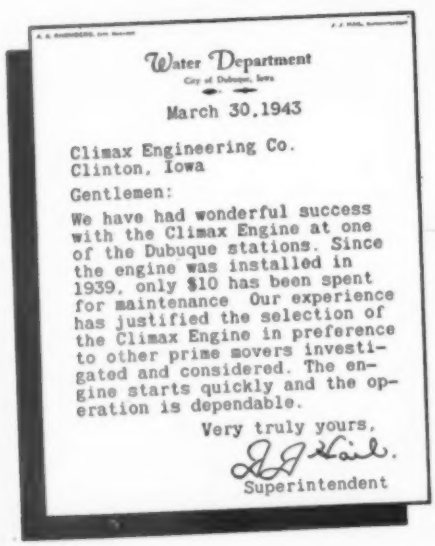
"We have had wonderful success with the

Climax ENGINE

at one of the Dubuque

pumping stations," says J. J. Hail Supt.





Water Department
City of Dubuque, Iowa

March 30,1943

Climax Engineering Co.
Clinton, Iowa

Gentlemen:

We have had wonderful success with the Climax Engine at one of the Dubuque stations. Since the engine was installed in 1939, only $10 has been spent for maintenance. Our experience has justified the selection of the Climax Engine in preference to other prime movers investigated and considered. The engine starts quickly and the operation is dependable.

Very truly yours,
J. J. Hail.
Superintendent

Mr. Hail's success substantiates that of municipal engineers throughout the country, who find that Climax Engines—used for normal power or stand-by service—deliver abundant, hard-hitting reliable power at extremely low cost.

These versatile prime movers are 4, 6, 8 and 12-cylinder internal combustion engines of 8 to 435 hp. Their ability to run on a variety of fuels gives them a flexibility unknown to steam, oil or electric power units. The simple, well-balanced design promotes high mechanical efficiency and easy, low-cost maintenance.

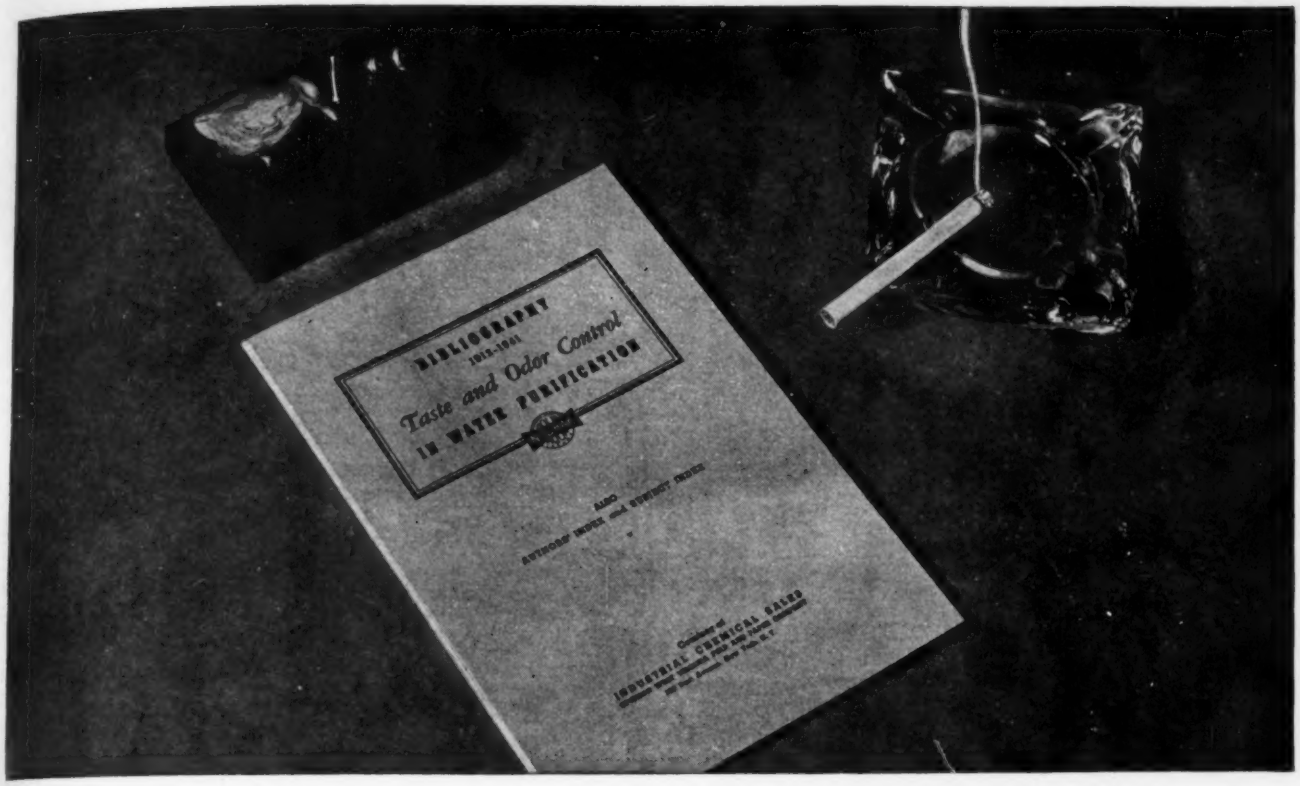
DESCRIPTION OF UNIT

The Dubuque engine is an 8-cylinder Model R8I Climax Blue Streak, rated at 240 hp. at 1200 r.p.m. Used in stand-by service, it burns gasoline. It is connected to one end of the high head DeLaval turbine pump through a quick detachable flexible coupling. The pump is normally driven by a 200 hp. synchronous motor.

Climax Engines and Generating Sets are designed, rated and equipped for the particular job to be done. Learn what a Climax will do for you—tell us your horsepower requirements, load characteristics, local fuels available, etc. With this information, Climax engineers will recommend a plant "tailored" to do your job to assure maximum dependability and highest economy. No obligation, of course. Write Dept. K at the address below.

ARMY E NAVY
"For High Achievement in the Production of War Material"

Climax
Engineering Company
GENERAL OFFICES & FACTORY
CLINTON, IOWA
REGIONAL OFFICES: CHICAGO, ILL., DALLAS, TEXAS



On your desk in 24 HOURS

Here is a bibliography of "Taste and Odor Control in Water Purification" from 1912 to 1941 which is yours for the asking. This covers nearly 900 articles, and contains authors' index and subject index attractively bound in a size that is easily filed.

If you are interested in taste and odor control in water purification and do not receive our monthly journal, advise us at once and we will include your name on our mailing list. Of course there is no obligation.

Yes! its yours for the asking

If you plan to attend the conference on War Winning Water Works Operation at the Carter and Statler Hotels, Cleveland, Ohio, June 15th-18th, here are two helpful suggestions:

1: Make hotel reseravtions promptly.

2: Arrange transportation and be sure that return Pullman space is secured.

☐ Please send me bibliography of "Taste and Odor Control".

☐ Please include my name on your mailing list to receive your Taste and Odor Control Journal each month.

Name .....

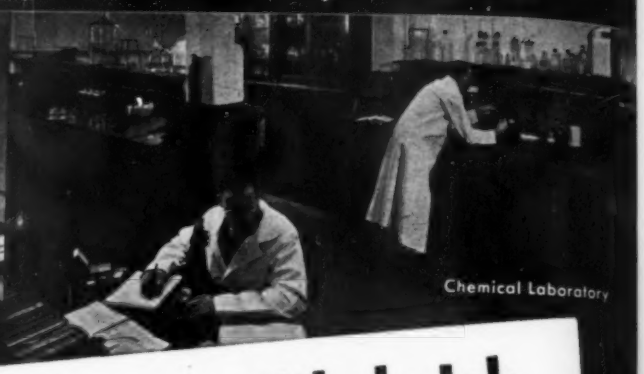
Address .....

.....

Industrial Chemical Sales Division
West Virginia Pulp and Paper Company
35 E. Wacker Drive, Chicago, Illinois

From Laboratory to Working Unit...

Engineering Department



Chemical Laboratory

Planing Steel Plate

Rolling and Forming

Dishing Heads

Graver Does The Whole Job

All Graver Water Conditioning Equipment is completely Graver-built from start to finish. There is no "jobbing out" of work. No sub-contractors enter into the picture. The service is complete and the responsibility is undivided.

- Your raw water supply is given a thorough study and analysis in Graver laboratories.
- The proper equipment to meet your specific requirements is designed by Graver engineers alone or in cooperation with your engineers.
- The equipment is built in Graver plants by Graver workmen under the supervision of Graver engineers.
- And the installation is made under Graver supervision or by your contractor with such help from Graver engineers as he may desire.

That's what we mean by complete service and undivided responsibility.

If you are planning to invest in water conditioning equipment of any type, bear these facts in mind — and consult Graver. We'll gladly discuss your problems with you and submit quotations without obligation.

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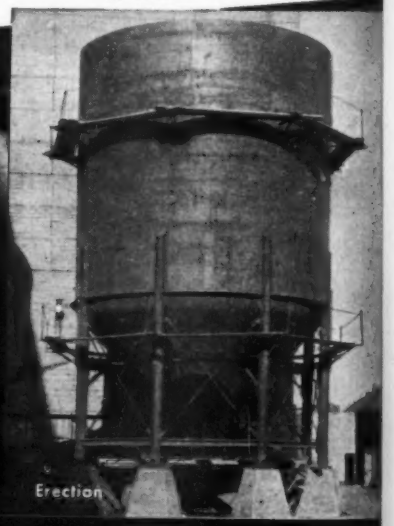
Welding



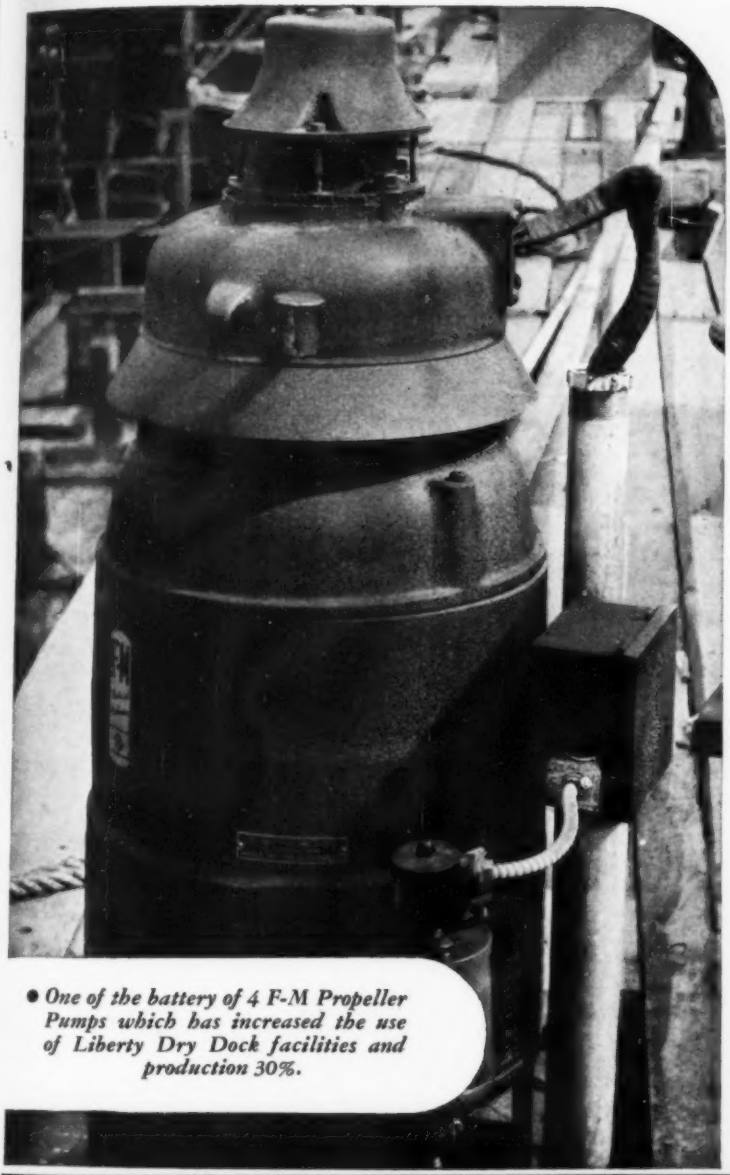
Erection

GRAVER

Water Conditioning Equipment

43-29-W

4 New F-M Pumps Help Speed Shipbuilding



• *One of the battery of 4 F-M Propeller Pumps which has increased the use of Liberty Dry Dock facilities and production 30%.*

That 4 new pumps, or any other unit of a construction program as complicated as shipbuilding, could increase a shipyard's production as much as 30 per cent seems almost incredible. But that is what happened at the Liberty Dry Docks.

With the inauguration of the high-speed shipbuilding program brought about by the war, the Liberty Dry Docks replaced certain steam pumping equipment with four 12-inch Fairbanks-Morse Propeller Pumps with stainless steel shafts and bronze propellers. Each pump is driven by a 20-hp. F-M hollow shaft slip ring motor.

Since installation, these pumps have increased the speed at which the dry docks can be raised and lowered to such an extent that an actual *30% increase* in the shipyard's production has been achieved.

Many old pumps, even if in factory-new mechanical condition, exact as high as 25% power cost penalty, as compared to F-M Pumps of modern design. Today—when *speed* is paramount—the greater efficiency of modern pumps means correspondingly greater speed.

Equipment to increase speed of production is available on priority. Use your priority to get Fairbanks-Morse pumping equipment—no slowdown, no breakdown, no stoppage. *Buy for today—with an eye for tomorrow!* Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago. Branches with service stations throughout the United States and Canada.

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STOKERS
AIR CONDITIONERS
RAILROAD EQUIPMENT

Pumps

% Bring Your CHEMICAL FEEDING PROBLEM to "Chemical Feeder Headquarters" %

For Pumped Water Systems — Constant Rate Feeders
Manual Adjustment

Fig. 1—Heavy Duty Midget Chlor-O-Feeder

Fig. 2—High Pressure Midget Chem-O-Feeder

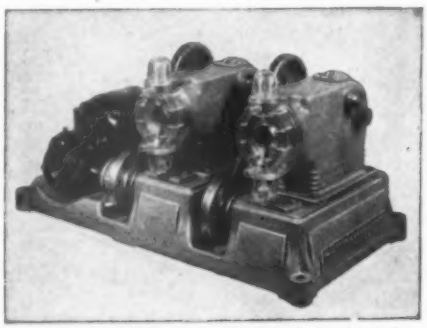

Fig. 3—Duplex Multi-control Feeder

Fig. 4—Triplex Multi-control Feeder

Whether your water system is pumped or gravity flow, low or high pressure, %Proportioneers, Inc.% is prepared to furnish you with equipment and service on all your Chemical Feeding (chlorination, ammoniation, calgon, soda ash, lime, alum, etc.) and Proportioning Problems. You are obligated in no way if you send for bulletin information, engineering recommendations, or quotations.

For Gravity Flow Systems — Flow Proportional Feeder
Automatic Adjustment

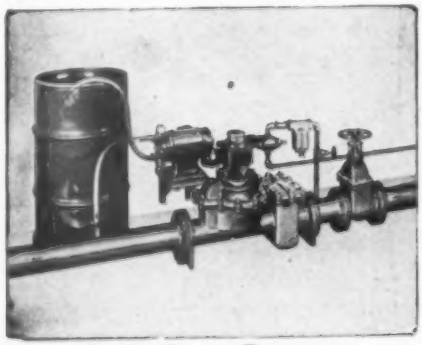

Fig. 5—Lowe Pressure Chem-O-Feeder

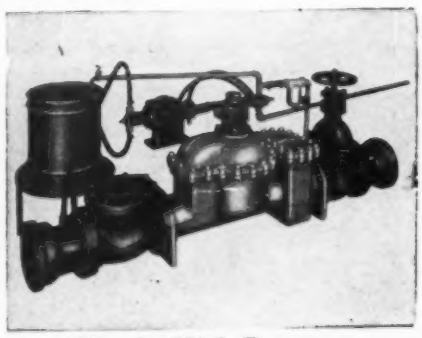

Fig. 6—High Pressure Chem-O-Feeder

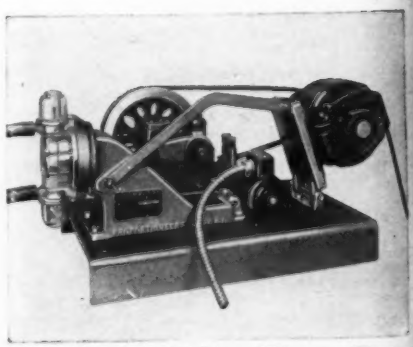

Fig. 7—Belt Shifter Heavy Duty Midget Chlor-O-Feeder

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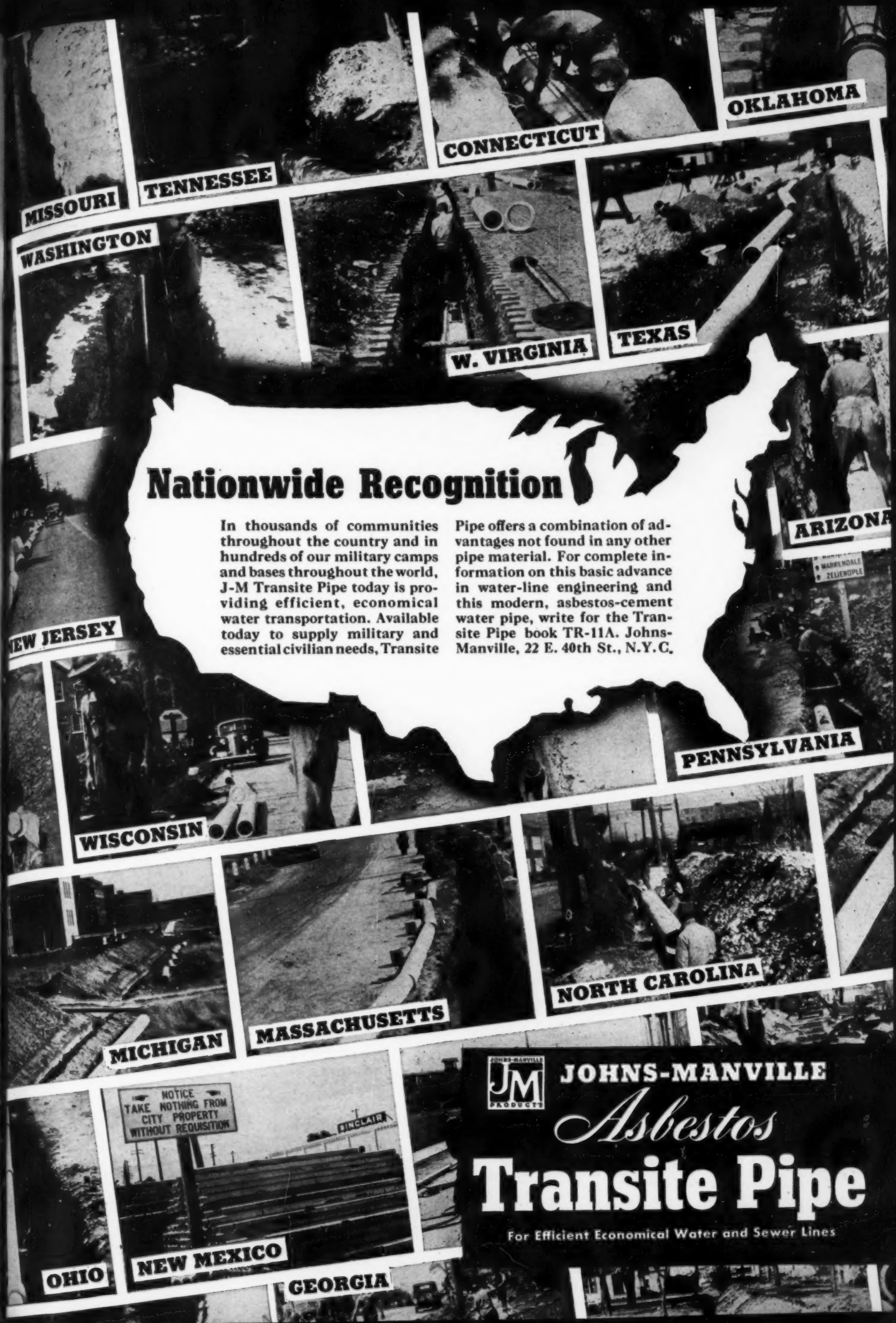
9N CODDING ST., PROVIDENCE, R. I.



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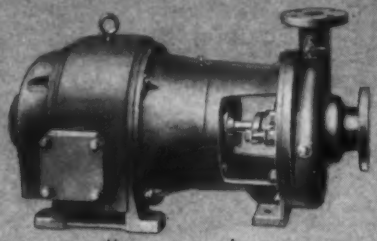
In thousands of communities throughout the country and in hundreds of our military camps and bases throughout the world, J-M Transite Pipe today is providing efficient, economical water transportation. Available today to supply military and essential civilian needs, Transite Pipe offers a combination of advantages not found in any other pipe material. For complete information on this basic advance in water-line engineering and this modern, asbestos-cement water pipe, write for the Transite Pipe book TR-11A. Johns-Manville, 22 E. 40th St., N.Y.C.

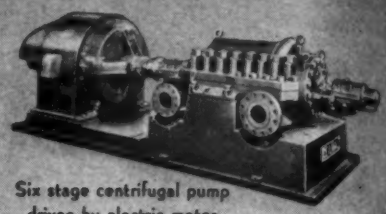
JM PRODUCTS

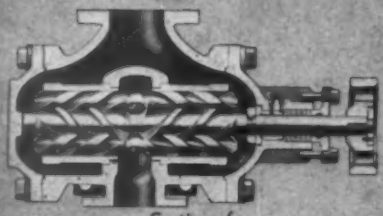
JOHNS-MANVILLE *Asbestos* Transite Pipe

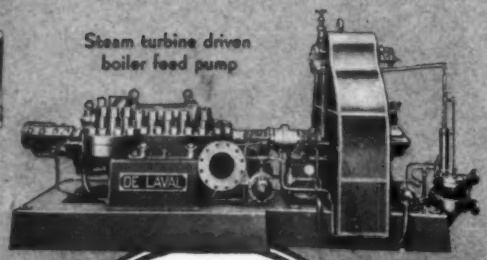
For Efficient Economical Water and Sewer Lines

Single stage, double suction pump with motor drive

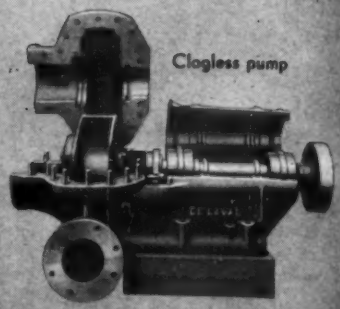

Motor-mounted pump


Six stage centrifugal pump driven by electric motor

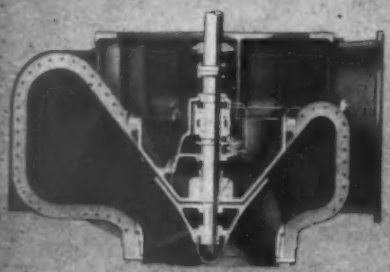

Section of De Laval-IMO oil pump

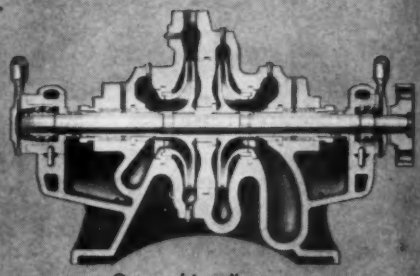


Steam turbine driven boiler feed pump

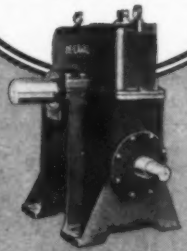

Clogless pump

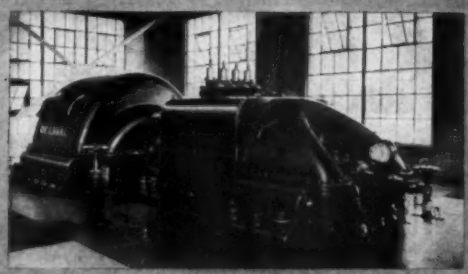
DE LAVAL Products


Mixed-flow pump

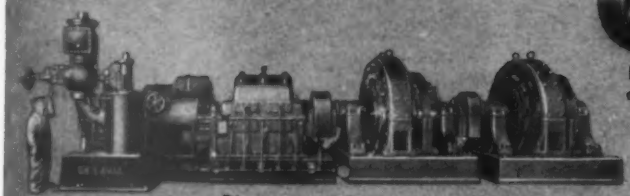

Opposed impeller pump

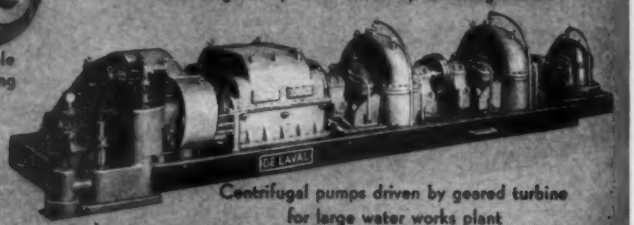
Steam turbine driving alternator


Worm gear


Multistage compressor driven by multistage turbine

Flexible coupling


Direct current generators driven by geared turbine



Centrifugal pumps driven by geared turbine for large water works plant

State requirements so that appropriate catalog may be sent.

3228

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MANUFACTURERS OF TURBINES . . . STEAM, HYDRAULIC PUMPS . . . CENTRIFUGAL, CLOGLESS, ROTARY DISPLACEMENT, MOTOR-MOUNTED, MIXED-FLOW, PROPELLER, PRIMING SYSTEMS . . . CENTRIFUGAL BLOWERS and COMPRESSORS, GEARS . . . WORM, HELICAL and FLEXIBLE COUPLINGS

VISIT OUR BOOTH NO. 30 AT THE HOTEL STATLER DURING THE AWWA CONVENTION

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ZEOLITE is proud of the extensive use of their products in the war effort. Uncle Sam's needs must come first. When delays in fulfilling your requirements occur your cooperation is appreciated.

ZECO and HI-ZECO Greensand Zeolite for water softening, filtration and iron removal. ZECO Manganese Zeolite for iron and manganese removal. COREXITE mineral for corrosion control and water stabilization.

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Pioneer Producer of GREENSAND ZEOLITE MINERAL

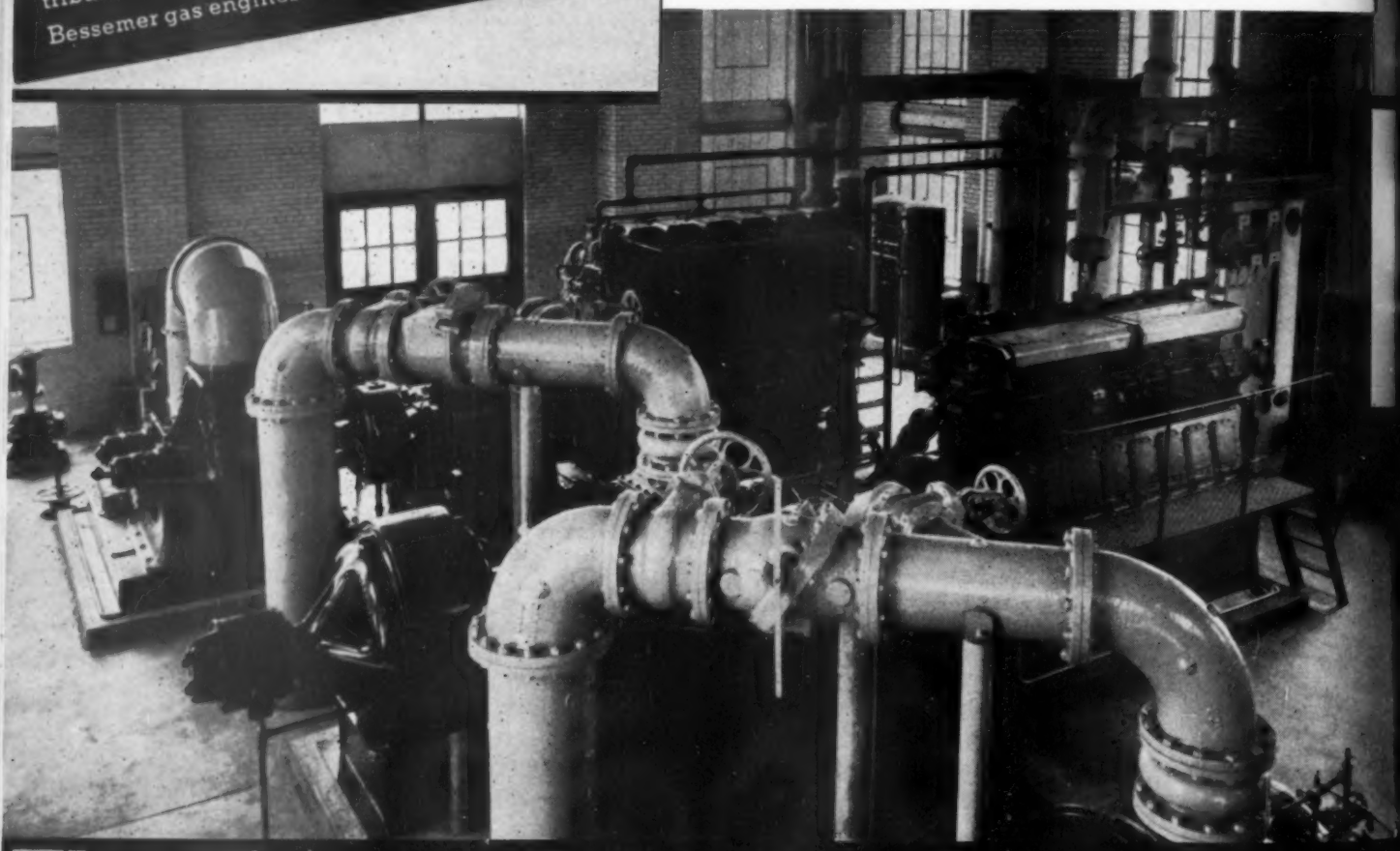
MADISON KEEPS THEM PRODUCING...

The record of operating economy and efficiency at the Madison sewage power plant is a tribute to the performance of these two Cooper-Bessemer gas engines—rated 230 and 320 hp.

A 60% saving in total power cost! Sufficient to pay the entire cost of the power plant in only four years!

That's the story at the Madison Wisconsin sewage disposal plant where they gradually converted from purchased power to self-produced power. No wonder they keep their two Cooper-Bessemer gas engines "producing" constantly! The first C-B engine was installed in 1937 . . . and another in 1939—both operating on sludge digestion gas.

Credit for such economy goes largely to "costless" sludge gas. Still, it's more than a question of fuel! All Cooper-Bessemer engines, sludge gas, natural gas, and Diesel, have the engineered efficiency . . . the reliability . . . and the remarkable ease of maintenance that time after time are the deciding factors in outstanding performance.



The Cooper-Bessemer Corporation

MOUNT VERNON, OHIO GROVE CITY, PENNA.

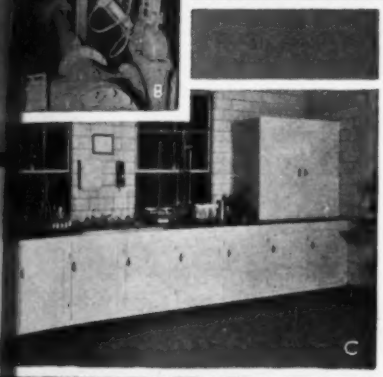
New York Washington Tulsa Dallas St. Louis Houston Los Angeles Seattle Shreveport

A MODERN ALL-STEEL FILTRATION PLANT for Beckley, West Virginia

by PITTSBURGH • DES MOINES

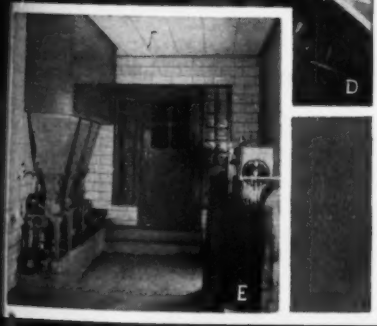
FROM AERATOR TO RESERVOIR— ALL WATER HANDLING EQUIPMENT IS STEEL

-A-
Mixing chamber, aerator, and sedimentation basins.



-B-
Filter piping and pipe gallery.

-C-
Laboratory



-D-
Operating floor: filters, operating platform and table.

-E-
Chemical equipment room.

SERVING the progressive West Virginia City of Beckley with a capacity of 2,000,000 gallons per day of purified, sparkling-clear water, this Pittsburgh-Des Moines filtration plant features the use of welded *steel* at every point in the water-handling sequence. Steel is employed for permanence, absolute water-tightness, low maintenance and freedom from cracking or other damage from ground movement or frost. A coat of paint at proper intervals is all that is required to keep the equipment in sound condition for a lifetime.

SEQUENCE OF FLOW

In the Beckley plant, raw water enters through an aerator to a steel mixing chamber provided with mechanical agitation, then flows through two steel spiral baffle sedimentation basins into the steel rapid sand filters (four in number, each with a capacity of 500,000 gallons per day), and then into the steel clear well units—one each of which is built integral with each filter. High service pumps then draw water from the clear wells, delivering it into a one-million gallon capacity reservoir of welded steel, which is located a mile and a half distant from the plant at the high point of the supply main to the city.

OTHER EQUIPMENT

The filter building contains—in addition to the four filter and clear well units—the pump room, chemical equipment room, chemical storage room, laboratory, work room and furnace room. In addition to the two high service pumps, the pump room contains two low service pumps for use during low-water periods at the dam when gravity flow through the system is prevented.

DESIGNED FOR THE FUTURE . . . TODAY!

As the City of Beckley grows, capacity can be added to the filtration plant according to plan, with minimum rearrangement and expense—assuring a continuous water supply of highest quality to the consumer. Thus, Beckley's investment—low in first cost and low in depreciation through economical layout and construction—is designed to return consistent dividends for many years. For a Pittsburgh-Des Moines consultation on the application of a STEEL FILTER PLANT to the water treatment problems of your own municipality, write to the nearest office of this company.

PITTSBURGH • DES MOINES STEEL CO.

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3412 NEVILLE ISLAND	913 TUTTLE STREET	ROOM 915, 270 BROADWAY	1216 FIRST NATIONAL BANK BUILDING	1217 PRAETORIAN BUILDING	619 RIALTO BUILDING	1120 EIGHTH AVE., SOUTH

Anybody Worried about the FUTURE?

WITH THE WAR'S DEMAND for speed in construction and production, every vestige of formality in design, every adherence to doing the job in the same old way, has disappeared. Large scale projects have eliminated tradition and have opened the eyes of engineers, designers and industrialists to new and better products and methods of production, *en masse*. From here on out, Americans will not be satisfied to return to old, stereotyped procedures of building or of manufacture.

With our own eyes we can see what titanic projects will do for the future of America. In building heavy, power transmission lines for Basic Magnesium, Bonneville, Grand Coulee, Fort Peck, and Boulder Dam, we can visualize the new cities and industries that will be created through plentiful hydro-electric power, and the hundreds of thousands of new families who will farm the fertile, irrigated desert. In helping to construct overnight, new cities and military camps, we can see the necessity for building future roads, utilities and housing. Construction of complete airport lighting systems has given us the definite vision of a future air-borne, highly commercial America.

This is a BIG war and in fighting it, we have been building a large industrial backlog for the future—an assurance that American construction and production genius will make this country the most pleasantly livable place on the globe. No, we aren't worried about America's future.

Today, the 1700 men and women of the Ziebarth organization are putting in every bit of their energy and time into the winning of the war. They are doing it in the same manner that they have always applied themselves to Ziebarth Construction jobs—"Get the job done —ahead of schedule!"

For *your* heavy construction, now or in the future, contact Ziebarth Construction.

"The Story of Ziebarth Construction" tells executives how this leading contractor can help them. Gratis.

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CONSTRUCTION

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Plant superintendents, council members, city commissioners, and other officials, all are talking about war and its many urgent problems . . . and just as earnestly these same men are thinking of the urgent problems they will face after the war.

We sincerely believe that much of your post-war planning can and should be started now, when you and your consulting engineers have the opportunity to analyze your over-all program and prepare a plan of action which is commensurate with your future needs. Then, when the bell rings and you've torn up the last set of priority papers, you will be ready—engineered for immediate progress.

Simplex Valve & Meter Company has been collaborating in such long-time planning for over forty years. Our outlook, therefore, is broad and is based on sound experience. We know many of the problems involved and can offer the solution to most of them. We are prepared to help you plan for the future — starting today.

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Cool as a Cucumber

—AT 6 MILES A MINUTE!

MEET the fighter that's blasting the Axis out of the sky! It rockets along at better than 400 miles an hour . . . powered by a liquid-cooled engine. Ethylene glycol (permanent anti-freeze to you!) is an important factor in its cooling system.

Chlorine, prime processing agent in the manufacture of ethylene glycol, is but one of the many Mathieson products which are contributing directly to the production of war materials. To mention only a few of the essential war uses of Mathieson chlorine, it plays an important part in the manufacture of aluminum . . . plastics . . . synthetic rubber . . . petroleum products and high explosives. Other basic "war chemicals", manufactured by The Mathieson Alkali Works and supplied directly to war industries or to our armed forces, include caustic soda, ammonia, soda ash, carbon dioxide and calcium hypochlorite. A highly mobile, dry chlorine carrier, calcium hypochlorite is used extensively at training centers and other military establishments to combat the deadly menace of waterborne diseases.

In a larger sense, Mathieson Chemicals are fighting a menace greater and more deadly than any the world has ever known—the arrogant, over-weening ambitions of the Axis tyrants, men without conscience and without mercy. Until they are removed forever from the high places of evil, there can be no let-up in the pace of war production here at Mathieson,

For outstanding achievement in the production of war materials.

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(INC.)
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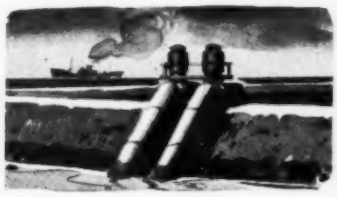
A TAP-FULL or a torrent!

PROJECT contractors selected Peerless Pumps to help build such power and irrigation developments as TVA, Bonneville, Coolidge, Norris, Shasta, Friant and Boulder Dams, and the Los Angeles Aqueduct. Hundreds are in service at other huge projects – the Chicago Subway, at Drydocks, Ordnance Works and for municipalities everywhere.



SALTY sea water is one of America's inexhaustible sources of magnesium. Peerless Hydro-Foil (Propeller Type) Pumps, with capacities up to 100,000 g.p.m., provide magnesium manufacturers with an unfailing water supply. At Panama Canal, in U.S. Flood Control service and at chemical plants other Peerless Hydro-Foils match these spectacular capacities.

GOOD NEIGHBORS. Everywhere abroad, Peerless installations abound. On Mexican haciendas, in Brazil's industries, in Peru's mines, in Cuba's sugar mills, for India's railways, on Hawaiian plantations, in Argentina's municipalities, it's "Peerless Pumps Preferred."

CONTACT. Wartime application of Peerless Pump engineers' knowledge of hydraulics is the successful development and application of Peerless gasoline and fuel oil pumps for direct refueling and transfer service at domestic and foreign bases for aircraft and at docks for ships.

SQUEEZES water uphill is the way owners describe the unique helical action of the chrome rotor pumping element of the Peerless Hi-Lift Pump shown above. A Hi-Lift provides 500 to 3500 gallons of water per hour. Municipalities, dairies, ice plants, laundries and hundreds of industrial concerns find it the answer to low cost, small capacity water supply.

ALLIGATORS are what the U. S. Marines call these amphibian tanks, that are as at home on water as on land. Here, again, Peerless' comprehensive knowledge of hydraulics brought Peerless Engineers the opportunity to do an extra part in the War effort by designing and building amphibian monsters which will speed America's Victory.

PEERLESS PUMPS—PROVIDE WATER FOR MOST EVERY INDUSTRIAL, COMMERCIAL AND DOMESTIC USE

In size, type of drive, choice of lubrication, for any depth or any practicable head, with lasting quality and sustained performance, your safest and most economical investment for lifting water is a Peerless Pump. Peerless Pumps' wide range of capacities can provide from 10 to 100,000 gallons of water per minute – a tap-full or a torrent.

PRE-ENGINEERING AND PRE-TESTING are the bases of customer preference. Peerless engineering and research are continual – results are enduring. Many of the "firsts" in water lifting are Peerless innovations.

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CUSTOMER PREFERENCE. Evidence of Peerless leadership is the roster of Peerless owners which contains thousands of industrial and commercial concerns whose names and products are household words, the world over. The benefits of the judgment and experience of their engineers are yours when you buy a Peerless Pump.

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Deep Well Turbine Pum
All forms of drive; electric direct-connected, right angle drive and belted head
Hydro-Foil (Propeller Type) Pump
Hi-Lift Pumps

Other Peerless Types
Centrifugal Pumps
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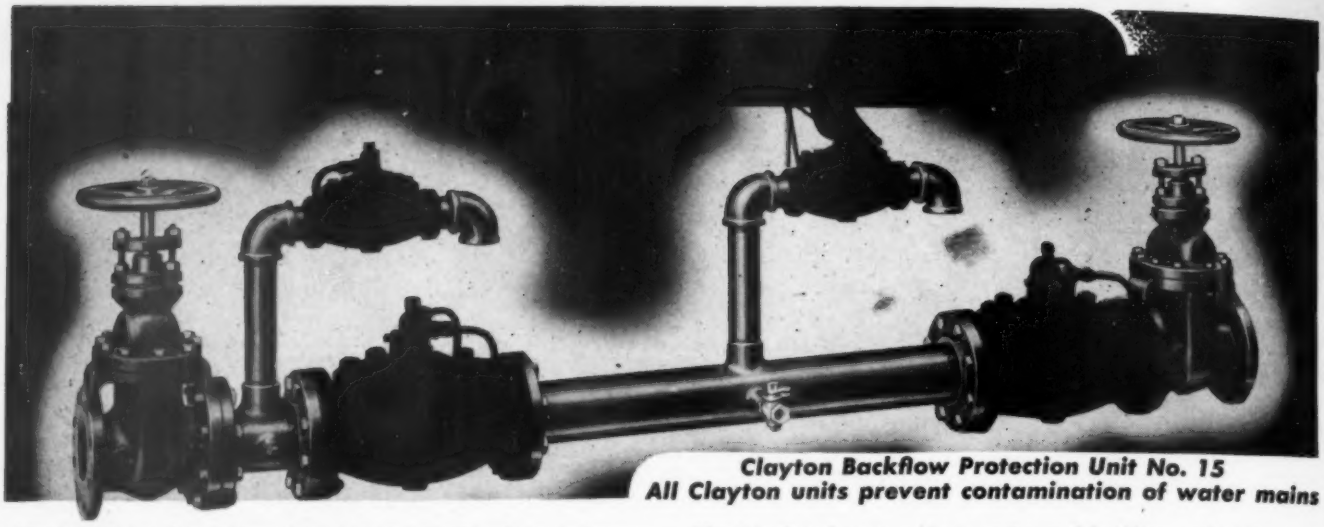
FACTORIES: LOS ANGELES, SAN JOSE AND FRESNO, CALIF.; CANTON, OH



Clayton Backflow Protection Unit No. 15
All Clayton units prevent contamination of water mains

Municipalities throughout America have suffered tragic losses through pollution of water systems caused by backflow and back-siphonage. To combat this public menace Clayton engineers have designed the Clayton Backflow Protection Unit which effectively prevents reverse flow in water systems.

Based on the hydraulic balance principle, already proven in thousands of installations of Clayton valves, the unit is completely automatic, gives visible indication of backflow, and is not affected by variations in pressure.

Municipal and state sanitary codes and building and safety requirements are met in its construction and operation.

The Clayton Unit provides complete break to atmosphere in the event of a pressure differential. It is positive in action, leak-proof and induces no line shock or water hammer. Units ranging from ¾" to 16" are available, ready for installation. Special units can be engineered to fit unusual problems.

Send for eight page folder describing method of operation and giving construction details and dimensions.

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Everson SterElatorS operate under a high vacuum (equivalent to 2" of Mercury). This feature not only increases their operational efficiency as chlorine feeders, but provides an important safety factor, for in case of water failure or gas line leakage the resulting loss of vacuum automatically shuts off the chlorine supply.

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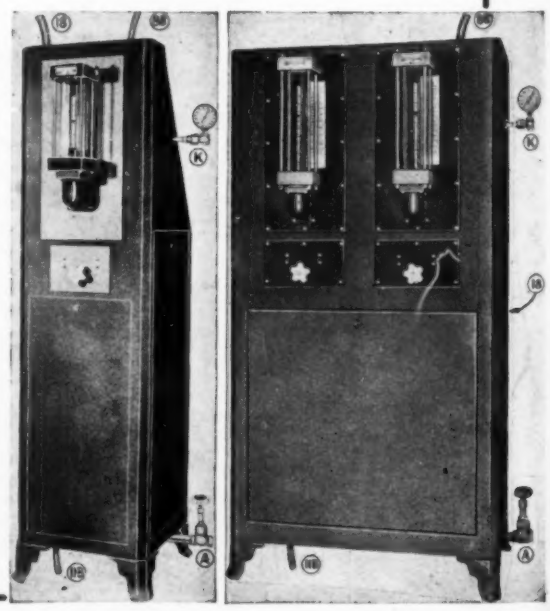

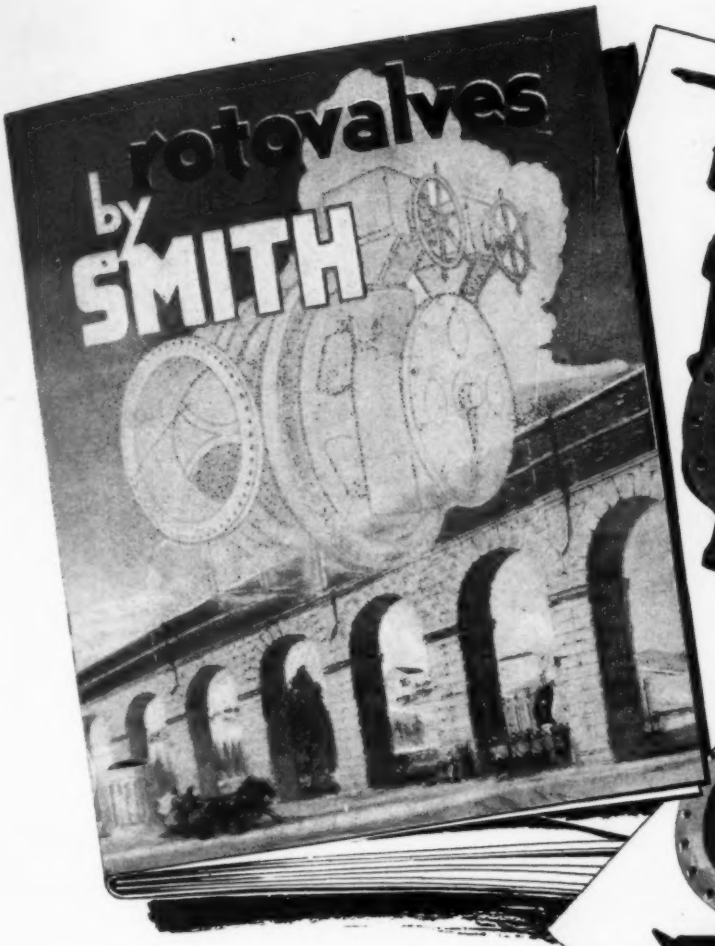

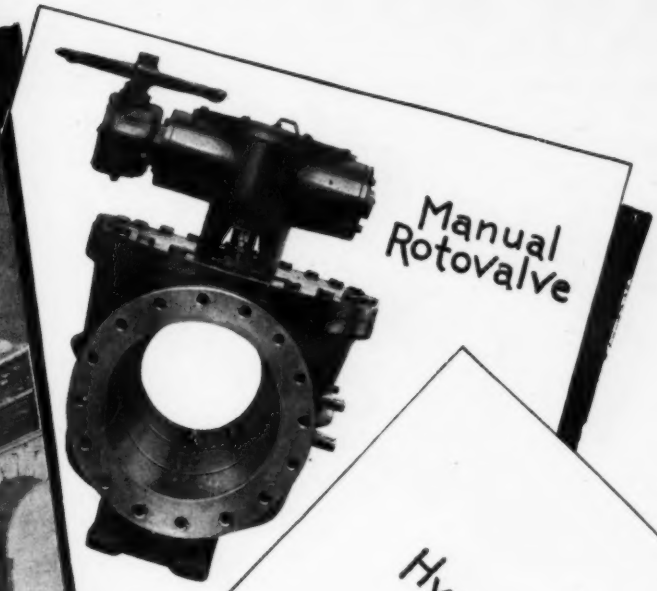

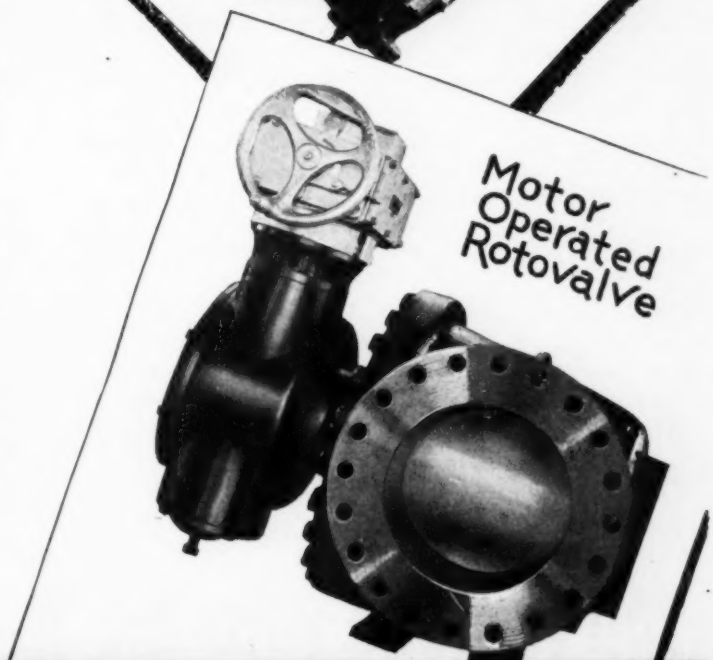

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And one thing more, these War Bonds are not only going to help win the war, they are also going to do much to close the dangerous inflationary gap, and help prevent post-war depression. The time and effort *you* now put in in selling War Bonds and teaching your workers to save, rather than to spend, will be richly repaid many times over—now and when the war is won.

★ ★ ★

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This space is a contribution to victory today and sound business tomorrow by
WATER WORKS AND SEWERAGE

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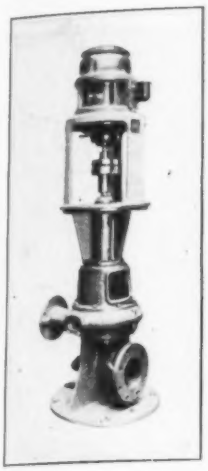
Send for data and literature. Economy's new Pump Data Book now available. Free—write for your copy on company letterhead.



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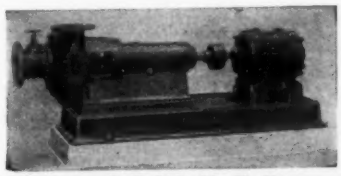

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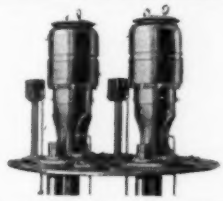

Duplex Submerged Type Pumps for either general or non-clog service.

Single Submerged Type Pumps. For either general or non-clog service.

Capacities
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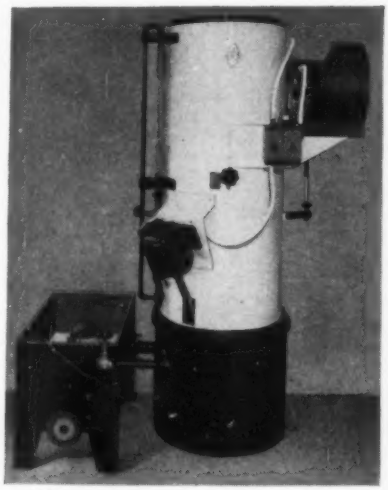
Vertical Pumps for Open Shaft Drive. Combination Supporting Base and Elbow with quick acting suction and case cleanouts.

Capacities
50 to 35,000 GPM

Economy Pumps Inc, Hamilton, Ohio



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Universal Dry Feeders
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Precision Solution Feeders
are kept in stock or can be assembled from stock parts within a few days.

Priority of AA-3 or better is required.

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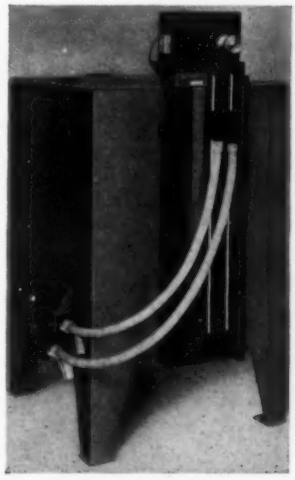

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COMING!

"The Control of Aquatic Vegetation"

Is the subject of an article relating the results from large scale experimentation and demonstrations with several methods of controlling the growth of various types of aquatic weeds and vegetative growths in the fresh water lakes of Wisconsin. Unfortunately, this article has been delayed but will be published in our next issue if the pressure of added wartime duties will permit the author to complete this seasonal article before the deadline for the July issue. The author is
L. F. WARRICK, State Sanitary Engineer, Madison, Wis.

"Sewage Tanks Financing and Joint Billing"

Is a contribution which outlines the method of arriving at sewer service charges involving a rate structure somewhat different from most methods of charging and billing for such service by a medium sized city which employs joint billing for water and sewer service but maintains separate accounts for each. The author is
JOHN A. GOETZ, Supt., Water and Sewer Department, Mattoon, Ill.

"The Control of Corrosion"

Is a well rounded out article on a topic of which it is impossible to know too much and concerning which there seems that much is still to be learned. We are privileged to offer this discussion of corrosion and its control in water supply practice by one who has probably a longer contact with the corrosion problem than any other water supply engineer. He is our water treatment patriarch—
ROBERT SPURR WESTON, Consulting Engineer, Boston, Mass.

"The Slough Flo-Meter"

Is the invention of a plant superintendent of a simplified flow-meter for water and sewage plants. The author and inventor—
JOHN D. SLOUGH, Supt., Sewage Treatment, Wellsville, N. Y.

"Operating Log and Record Forms for the Small Water Plant"

Represents a composite presentation of log and record forms considered meritorious by three State Sanitary Engineers, two of whom are former plant operators.

Plant Improvements at Spartanburg, S. C.

The installation of secondary treatment units and other sewage plant betterments at Spartanburg, S. C., are to be described by—
GEORGE W. WHITE, Howard Beebee Eng'rs, Spartanburg, S. C.

"Packinghouse Waste Treatment Which Yields a Return"

Is one of the series of articles on industrial waste treatment which have been appearing in this magazine. This one tells of a process developed by Swift & Co.'s Research Laboratories that yields a product useful as stock feed to defray the costs of purification of protein rich packinghouse wastes. The authors—
CAPT. M. D. SANDERS and E. N. MORTENSON, Chemical Engineering Division of Swift & Co.

"Dependability of Double Check Valve Installations"

In response to a number of requests in recent months asking for advice as to the relative merits and dependability of approved Factory Mutual type double check valve installations between public and private fire protection systems, the forthcoming article has been prepared at our request. It represents the best record available of the extent to which approved double checks constitute dependable protection to public water supply against private fire service back flow into the mains. The author is—
F. O. A. ALMQUIST, Senior Eng'r, State Dept. of Health, Hartford, Conn.

"An Improved Method of Grease Determination in Sewages and Sludges"

Is the contribution of the Water and Sewage Division of the N. J. Agricultural Experiment Station, which presents an improved method for the determination of grease in sewages, trade wastes and sludges. The author is
DR. H. W. GEHM, Associate, N. J. Agricultural Experiment Sta., Rutgers, Univ.

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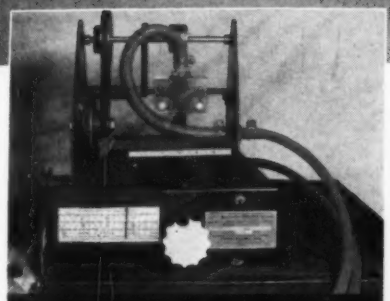
AN **A-1** HYPO-CHLORINATOR, AT THE A.W.W.A. CLEVELAND CONVENTION — JUNE 15 TO 18, SPACE NO. **A-1**

Var-I-Feeder Wired to proportional Control Meter enclosed in Sheet Steel Case for permanent water plant installation.



Var-I-Feeder removed from portable case. In addition to features already mentioned note visible illuminated reagent head, and external pulley for belt connection to gasoline engine or available R. P. M., if current for motor drive (1/20 H. P.) is not available.

Illustrating extreme portability

Portable model in operation

AS SIMPLE AS TUNING IN YOUR RADIO

DOSAGE AND RATE-OF-FEED CONTROLLED WITHOUT STOPPING VAR-I-FEEDER, BY JUST TURNING SMALL HAND WHEEL

But that's only one of many innovations. Following are some of the others:—

1. **ILLUMINATED INSTRUMENT TYPE CONTROL PANEL** — Scale indicates gallons solution fed per hour, pounds chlorine fed per hour and gallons per hour of pumpage being treated. The operator may calibrate other scales on the dial for his own special uses.

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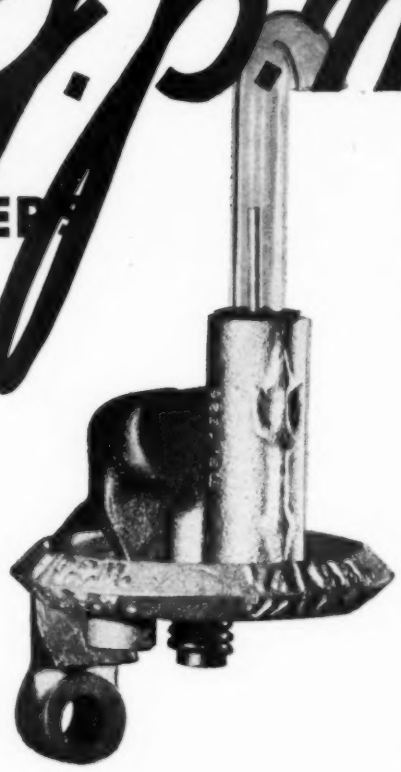
CHEM-FEEDS-INC.

77 RESERVOIR AVE., PROVIDENCE, R. I.

Jeff Snyder **PRESIDENT**

Orifices vs. g.p.m.

IN TESTING WATER METERS



WITH a 1/16" stream (a 1/16" orifice in a thin plate) at 60 lbs. per square inch, the smallest rate of flow will be about half a gallon a minute: and depending on the edges of the hole, it might run as high as 9/10 g.p.m.

EVEN with only 40 lbs. pressure the minimum would be .44 g.p.m., a flow which is still nearly double the desired low flow test rate for the 5/8" meter.

HOWEVER, with a good rate of flow indicator it is possible to obtain easily and with accuracy, at any pressure, the desired test rate of 1/4 g.p.m. for the 5/8" meter. This is next to impossible with a fixed orifice.

THE Neptune Rate of Flow Indicator is a simple, positive, and inexpensive device which may be applied to any test bench. Your Neptune Representative will be glad to arrange for a demonstration.

WATER WORKS & SEWERAGE

VOL. 90, No. 6 *A Gillette Publication* JUNE, 1943

HOW CRITICAL WAR MATERIALS WERE SAVED AT ATLANTA

Through a Project of Renovation and Rustproofing Applied to two Filter plants

By PAUL WEIR
Asst. General Manager
DEPARTMENT OF WATER
ATLANTA, GA.

The Author*

*The author has the distinction of having just been chosen National Director of A.W.W.A. by the Southeastern Section, and elected chairman of the Southeastern Section of A.S.C.E.

IN the Spring of 1942 the Atlanta Water Department entered upon a rustproofing and waterproofing project at two of its filter plants. The 21 M.G.D. reinforced concrete gravity plant is 20 years old, and the 18 M.G.D. steel tank pressure plant is 50 years old. "No-Ox-Id" XX was used for both purposes very successfully.

The gravity plant consists of seven, 3 M.G.D. reinforced concrete filters. The renovation work included the waterproofing of approximately 35,000 sq. ft. of reinforced concrete surface, and rustproofing 27,500 sq. ft. of 2½" diameter cast iron filter laterals, manifolds and 200 gate valves, varying in size from ¾" to 42".

The pressure plant consists of a battery of 36 horizontal steel filter tanks arranged in two rows. Each unit has the capacity of 500,000 gal-

Section of a Renovated Concrete Gravity Filter
(Concrete surfaces waterproofed; cast iron manifold and laterals cleaned and rustproofed inside and out.)

lons per day. The individual units are 8 feet in diameter, 20 feet in length and hold approximately 7,000 gallons of water. In addition to cleaning and rustproofing these metal filter tanks, 425 valves, ranging in size from 4" to 36" are being put in first-class condition. Since this plant was installed in 1893, it might normally be assumed to have served its useful life; but as a result of the rustproofing program, it is believed that the plant is now starting upon its second 50 years of service to the city.

The Program and Procedure

The program of renovation was planned some time before Pearl Harbor; but the actual purchasing of supplies was not done until after that tragic date. We, therefore, have endeavored to utilize materials requiring a low priority rating, if any.

Since the protective coating selected had already been determined upon from previous information, tests and data, this article will be confined to a description of valve renovation, surface preparation and coating application procedures. It should be understood that choice of materials is a most important consideration and is worthy of thorough investigation. Our own investigation led to the use of "No-Ox-Id" coating, a high melting paint wax containing rust inhibitors, which is effective both as a waterproofing and as a rustproofing agent. (See details in tabulation of materials and labor).

As Applied at the Gravity Filter Plant

The sand and gravel were removed from the filters by means of a hydraulic water ejector and discharged through a 4-inch pipe to a cleaning and regrading plant outside of the filter building.

Cleaning the Interior Walls of a 50 Year Old Steel Pressure Filter by Use of the "Flame-Priming" Acetylene Torch.

The 2½" filter laterals were cleaned of rust adherent scale by sand blasting both inside and outside. They were then dipped into a vat of "No-Ox-Id XX" which was maintained at a uniform temperature of 250 degrees F. The dipping process required approximately two minutes. The laterals were next drained over the tank two minutes, and placed on the inspection rack to cool. After a final inspection, they were replaced in the filter bottom.

Treatment of Concrete Surfaces

The concrete filter walls and bottoms were irregular and badly cavitated, as the accompanying picture reveals. No effort was made to bring the walls up to a uniform contour. They were carefully brushed by hand, cleaned of all loose particles, washed and dried and treated with a 1/32" coating of "No-Ox-Id XX". This material was applied by means of a specially heated pump applicator which insured a uniform thickness of material and absolute coverage. Thereafter, a non-carbonizing flame from a kerosene-burning torch (weed burner) was applied gently to this new surface in order that the finished wall might have a uniformly smooth coating. This final smoothing process with the torch also showed up any holidays or missed spots. These were touched up and smoothed by flaming with a blow-torch. In connection with use of the torch in the smoothing process, it is well to mention that the torch should be held at an angle to the surface and be moved in such manner that the flame will strike the surface angularly. A slight sweeping effect to the movement tends to fill all pores better than perpendicular application of the flame.

Renovation of Hydraulic Valves

The hydraulic valves, which range in size from 8" to 42", were carefully cleaned by hand scrapes and power driven brushes. Necessary mechanical repairs were made, and the entire internal surface of the valve was coated with "No-Ox-Id A-Special". This was applied cold by hand, using a canvas glove and putty knife. The flame of a blow-torch was brought into contact with this material in order to obtain a uniformly smooth coating. Holidays and bare spots were detected by this method and touched up. New cup leathers were placed in all of the hydraulic piston chambers.

When all of the valves were finally replaced in service it was found necessary to reduce the original water pressure on the hydraulic system,

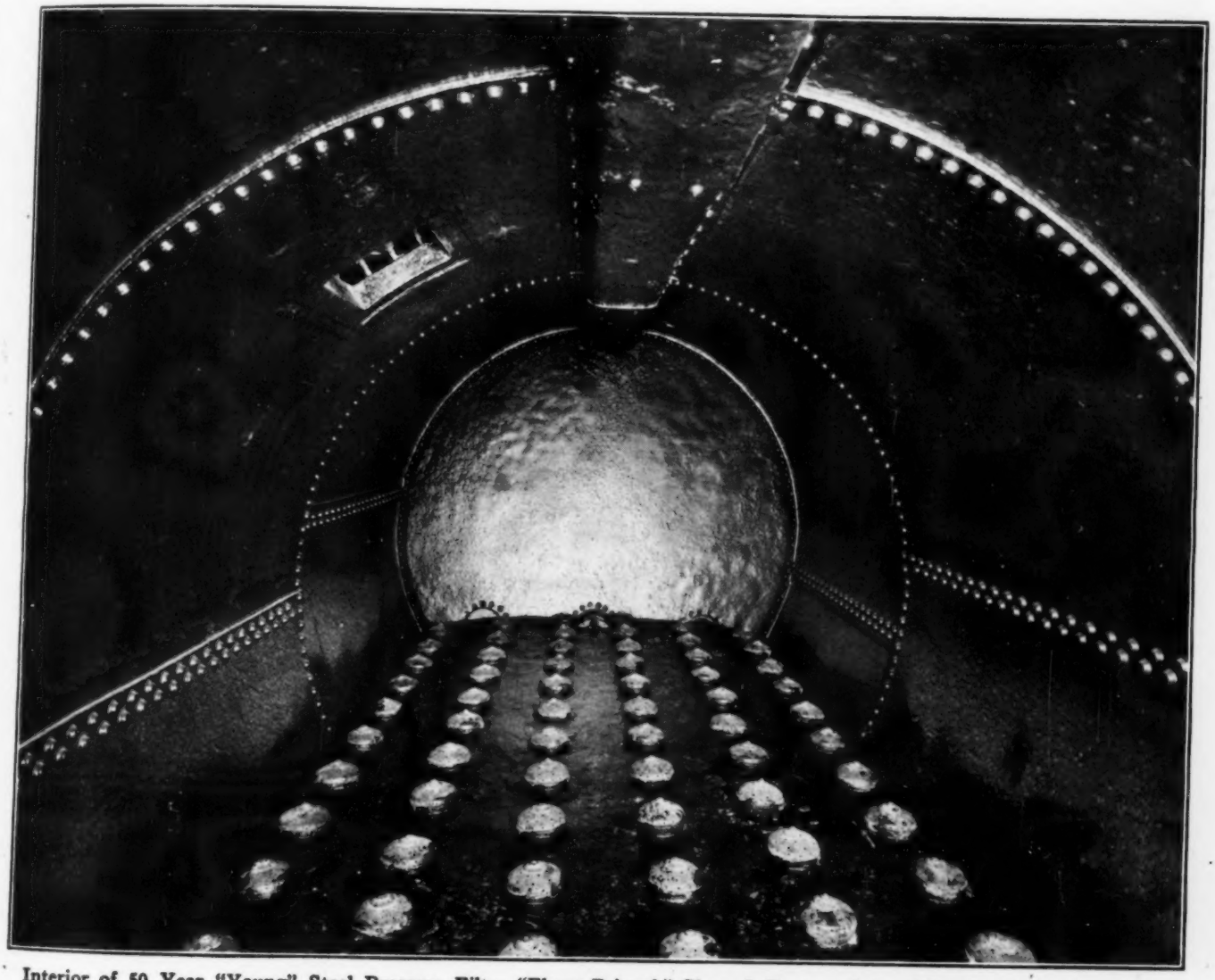
because of the ease with which the reconditioned valves operated.

After all reconditioning work was completed, the gravel was replaced in the filters in layers, and the sand was returned by means of an hydraulic ejector. Each filter bed was carefully checked to ascertain its hydraulic characteristics, sand uniformity, and effective size. For sterilizing the filter beds approximately 3 pounds of chlorine gas was used per million gallon capacity. After a period of 48 hours each filter was checked bacteriologically and returned to service.

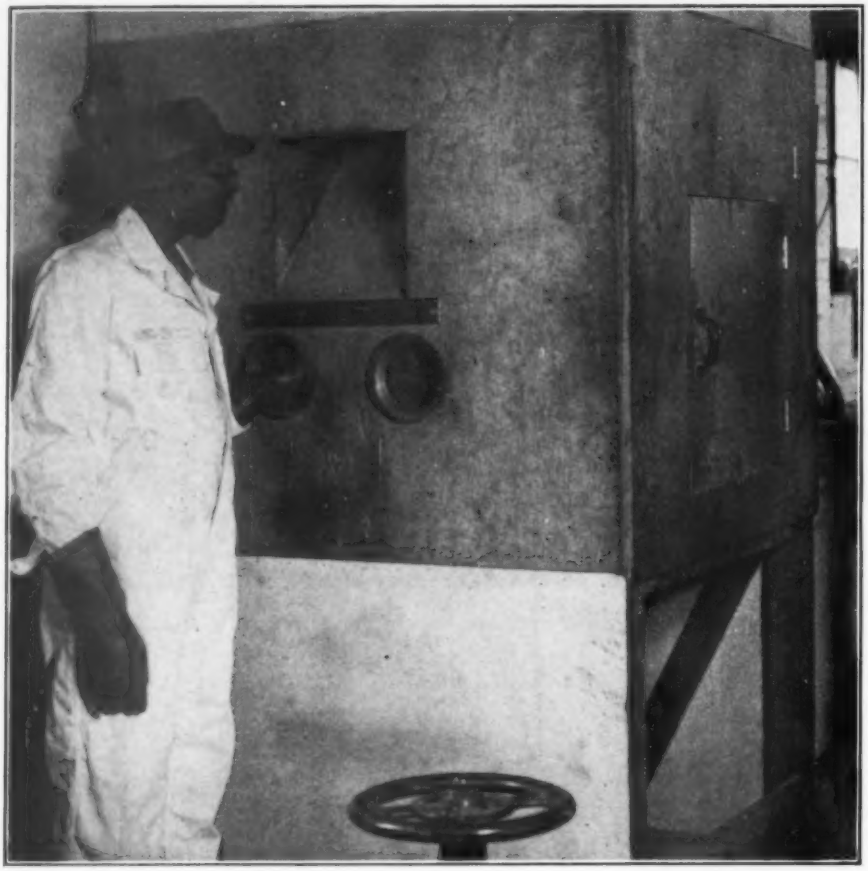
All work on the gravity filters was carried out by our local forces, who completed the job in approximately six months.

We have experienced no leakage in filter walls since this work was completed last October and the over-all efficiency of each filter has been materially improved. From the standpoint of rustproofing and waterproofing, they are better today than

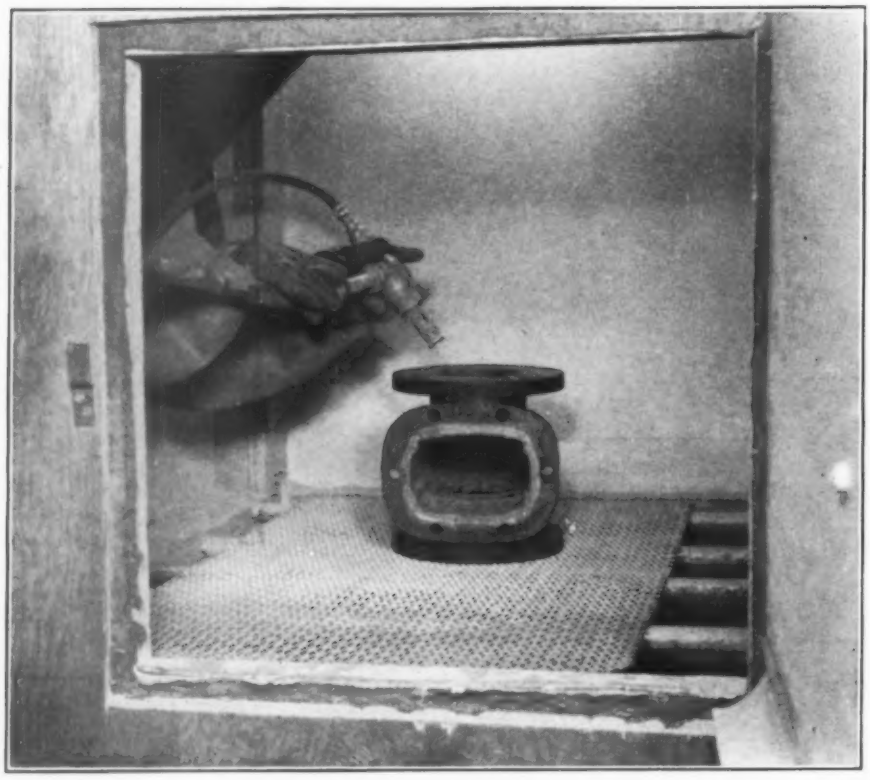
Section of One of the Steel Pressure Filters Before Cleaning and Rustproofing.



Interior of 50 Year "Young" Steel Pressure Filter "Flame Primed," Cleaned, Rustproofed and Ready for Another Half Century of Service.



The Sand-Blast Cabinet and Operator at Work on a 50 Year Old Valve.



Sand-Blast Cabinet Interior
(Showing detail of home-built blast nozzle and how used through rubber sleeved arm openings.)

they were 20 years ago when the plant was new.

Work at the Pressure Filter Plant

The oldest of the steel pressure filter tanks were placed in service about a half-century ago, and while it is impossible to give a complete understanding of their condition, the pictures show rather clearly the pitted and corroded condition of the equipment.

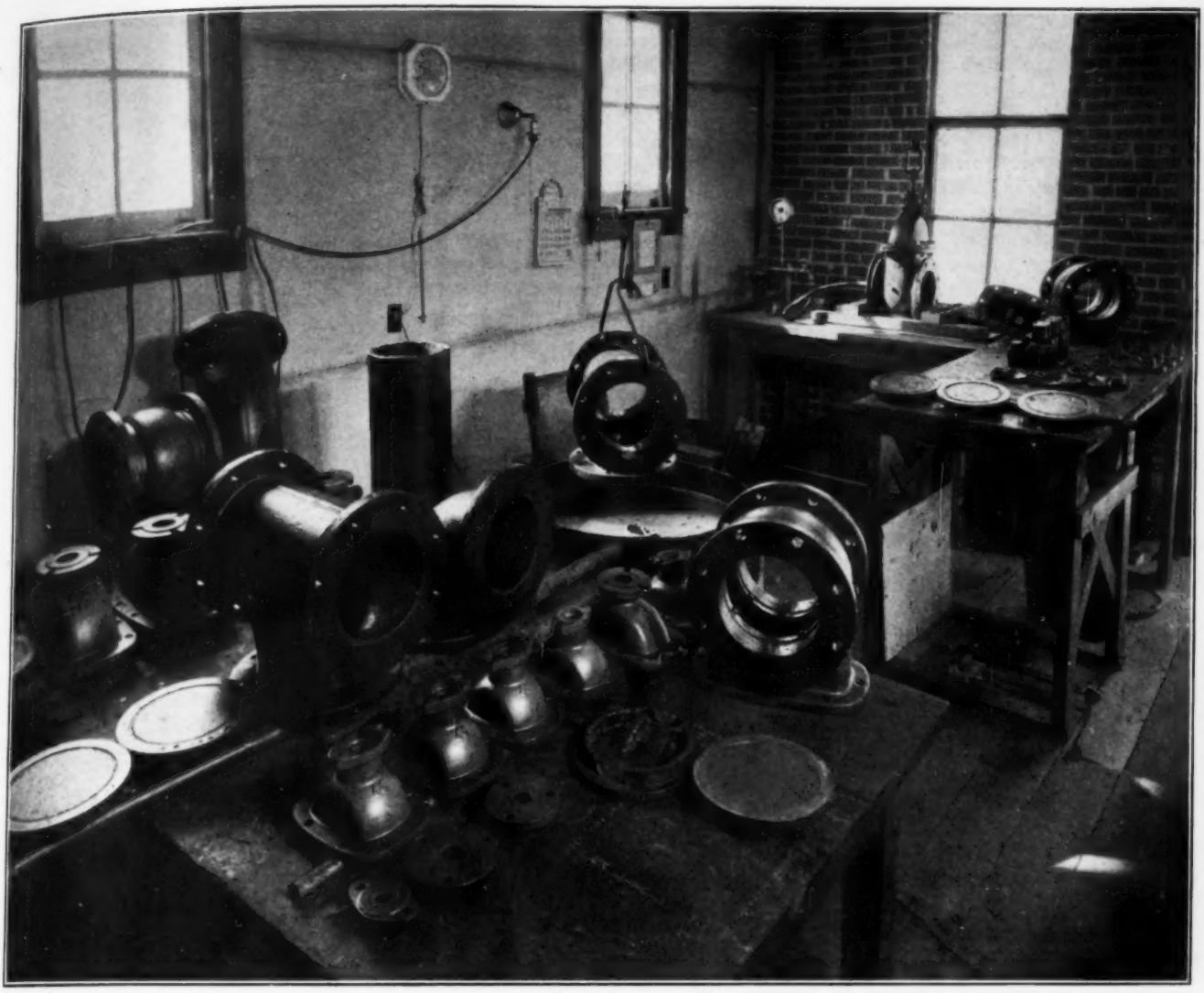
After the sand and gravel were removed by an hydraulic ejector and conveyed by 4-inch pipe to a washing and grading plant outside the building, it was found that the interiors of these filters were badly tuberculated; and in many instances, the original ½-inch metal thickness had been reduced to ¼-inch.

Surface Preparation by "Flame-Priming"

A number of different methods were used in attempting to remove the tenacious rust scale, the majority of which were unsuccessful. It was finally decided to remove all superficial and loose rust with billy shovels. An oxygen-acetylene flame-priming torch was used to dehydrate the remaining tenacious scale, which was readily removed by hand chisels and power driven wire brushes.

The flame-priming torch consists of a special ½" by 6" head, attached to a regular oxygen-acetylene handle, operated by means of a quick opening valve. It was furnished by the Linde Air Products Company. This equipment generated a temperature of approximately 6,200 degrees F. on the surface of the iron rust. Care was exercised not to overheat the area of the metal adjacent to the rivets. A 1200 cu. ft. per minute exhaust fan furnished fresh air in the tank through a second manhole.

After the interior of the filters was cleaned of all rust scale, the surface of the metal was heated to about 100 degrees F. by a large natural gas torch. This was done to free the surface of the metal from moisture of condensation. It should be emphasized, that in using any torch for this purpose, care must always be exercised to maintain an oxidizing flame. If a reducing flame is used, carbon or smoke deposits on the surface of the metal might seriously limit effectiveness of the bond between the rustproofing coating and the metal. Immediately after the drying process, "No-Ox-Id XX" was applied to the surface of the metal by means of our temperature controlled coater, which is both heated



"No-Ox-Id" Dipping Tank and Renovated Valve Parts

and motor operated from a 110-volt A.C. electric circuit. —See picture.

A natural gas burner was used to smooth up this coating in order that holidays and bare spots might be detected. A second application of the coating material was then applied, which resulted in a total thickness of about 1/16-inch. This was again flamed for final smoothness and the filter was ready to be recharged with gravel and sand.

Renovating Valves and Fittings

Valves in connection with the pressure-filters are all hand operated gate valves, with a history of from 30 to 50 years of continuous service. Most of these have been operated as throttling valves. The bronze faces on the gates, wedges and case rings, were badly worn and almost beyond repair. It was possible, however, to salvage bronze facings on about one valve in four. The other bronze faced gates, wedges and case rings were replaced with new parts by the Rensselaer Valve Company, the original manufacturer. It was possible to reclaim all other parts of the valves. They were returned to service when completely renovated.

All interior cast iron surfaces of the valves were badly tuberculated with rust and scale. We attempted to remove this material by means of hand scraping and power driven wire brushes. It required one person about eight hours to remove this scale by hand. It was impossible to properly clean corners and inaccessible areas, which predominated in the majority of the smaller valves reconditioned.

Development of a Sand Blasting Method

It was finally decided to remove the scale by means of sand blasting. This was accomplished by building a 4 ft. by 4 ft. by 8 ft. sand blasting cabinet, with a dust exhaust at the top. This was located on the filter operating floor. The photographs show in some detail the design and operation of this cabinet. The operator stands on the outside of the cabinet and operates the sand blast nozzle by reaching through two rubber sleeved openings in the wall of the cabinet. A 14 in. by 20 in. glass window, set at an angle and protected by hardware cloth, is provided so that the operator can view the progress of the sand blasting which takes place entirely within the cabinet, without coming in contact with the obnoxious dust. Two 200-watt electric lights, arranged in the ceiling of the cabinet, afford ample illumination. The exhaust fan keeps the cabinet reasonably clear of dust so that vision is good. There is, however, sufficient etching impingement on the glass window to require its replacement occasionally. Valves and fittings up to 18″ in size can he handled satisfactorily in this cabinet; but larger items are more conveniently handled by individual hand-cleaning methods.

In using the sand blasting cabinet, the casting to be cleaned is placed on a ¼" wire screen, supported on ¾" pipe the full width of the cabinet. A second reinforced 16-mesh screen constitutes the top of a steel hopper, which is installed 6" below the top ¼" screen on which the sand blast operation takes place.

About 300 pounds of sand is carried in the sand hopper, and this is drawn through a rubber hose from the bottom of the hopper to the sand blasting assembly by air pressure, then it is ejected out onto the metal surface to be cleaned. The ejected sand and rust particles are caught on the lower ¼" screen and the sand passes through the final 16" mesh screen, from whence it is returned to the sand hopper for recirculation to the air blast nozzle.

The ejector nozzle is also a home-made arrangement and consists of a ½" Y-lateral, or McDaniel suction tee, one leg of which is connected to the ¾" sand suction line, the second is reduced to ⅛" and receives the air line. The sand and air are ejected through the third ½" opening, into which is fitted a ½" by 3" nipple. Air pressure is maintained at approximately 90 pounds. Approximately 300 pounds of sand is used and re-circulated through the blasting system every hour.

While on the subject of sand, it should be pointed out that the character of sand is an important item in satisfactory sand blasting operation. The sand must be maintained in an absolutely dry condition, and a good grade of clean, sharp, silica sand must be provided in the first place.

The cast iron fittings are cleaned down to the bare gray iron in a surprisingly short time. It was soon discovered that the sand blasting would seriously cut all bronze surfaces and that some method of protecting them was essential. Knowing that "No-Ox-Id XX" would resist sand blasting, a heavy coating was painted on these surfaces and the entire fitting was then cleaned with the sand blast without damage to the bronze areas. The fact that the rust-proof coating selected resists sand blasting is another evidence that it will give long resistance to normal wear, when applied to the interior surfaces of the filters.

After the valves were sand blasted, all parts were cleaned of silica dust by hand wiping with clean rags and brushes. The parts were then dipped into a 50-gallon steel dipping tank of "No-Ox-Id XX", which was heated to 180 degrees F. by means of a 6" diameter household natural gas burner—see picture.

It is important to point out that no water, air, or steam should be applied to the metal surfaces after they are cleaned and ready for coating. If either water, steam, or air were used for removing adherent dust particles after sand blasting, the adherent moisture would result in initial oxidation of the surfaces and would prevent proper adherence of the coating. This observation is quite contrary to the opinion held by some engineers with whom we discussed the problem before establishing our procedure.

The Universal Hot Coater.
(For application of viscous coatings.)

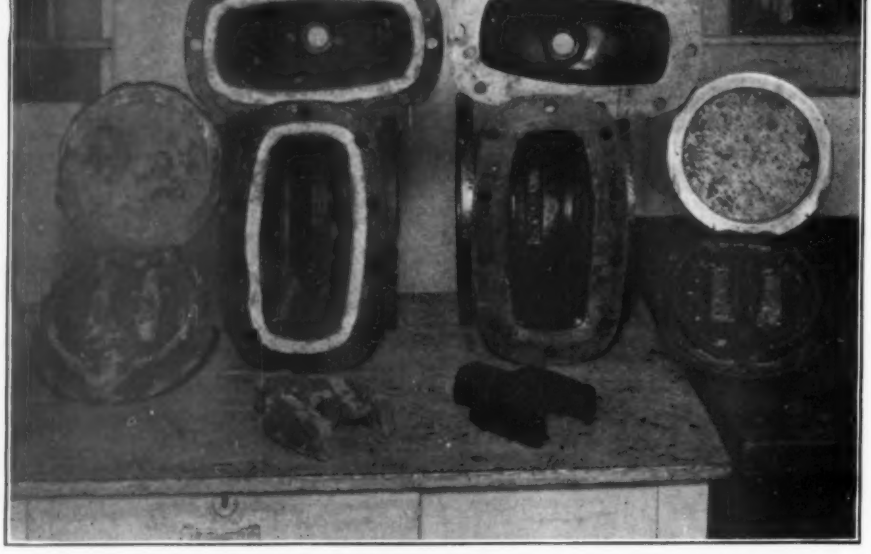
It was found necessary to maintain a uniform temperature of the "No-Ox-Id XX" in the dipping vat at 180 degrees F. This temperature resulted in a uniform protective coating. The time of dipping varies from two minutes to five minutes, depending upon the size of the casting. A small electrically operated hoist was used in the dipping process, and all fittings were allowed to remain suspended over the dipping vat approximately two minutes, after which they were placed on the inspection rack to dry and cool for final checking. All usable portions of the valves were then placed on the assembly table where the valve was reassembled and tested hydraulically at 25 to 100 pounds to insure proper operation.

Development of this procedure required many months of study and experimentation. The final results, however, are gratifying and permit us to further utilize an 18 M.G.D. filter plant which has already served the city for 50 years.

Conclusion

During our entire renovation program, we have endeavored to cooperate with the war effort by using limited quantities of those materials that require priority ratings.

The 21 M.G.D. gravity filter plant is already back in service and work of renovating the 18 M.G.D. pressure plant will soon be completed. Restoration of these units will materially assist Atlanta in meeting the ever increasing water demand, incident to the war effort. Had this program not been entered into, it is possible that our city would have had to make an extensive capital investment ne-



Fifty Year Old 8-Inch Gate Valves Before and After Renovation and Rustproofing.

cessitating the use of thousands of dollars worth of critical materials.

Acknowledgement—

The success of this work has been made possible by the cooperation and ability of our employees, especially Messrs. C. N. Davis, foreman; Sherman Russell, maintenance mechanic; W. E. Ogle, mechanic, and others.

Acknowledgment is also given for assistance rendered by Messrs. C. L. Armstrong, of the Dearborn Chemical Company; L. B. Eley and E. W. Deck, of The Linde Air Products Company; Preston Avery, of Rensselaer Valve Company, and other manufacturers' representatives.

The work was carried out under the supervision of the writer and at the direction of, and with the invaluable counsel of, Mr. W. Zode Smith, General Manager of the Atlanta Water Department.

MATERIALS AND EQUIPMENT

For the benefit of those interested the following listing of materials and equipment utilized is given.

Coating Materials:

"No-Ox-Id" — Waterproofing and rustproofing compound.

"No-Ox-Id XX"—A high melting point wax with rust inhibitor. Melting point 155 degrees F. Will not become brittle at 40 degrees below zero. Used for both rustproofing and waterproofing.

"No-Ox-Id A-Special"—For rustproofing. Hand application cold. Melting point 130 degree F. Use for rustproofing.

(These coatings were supplied by The Dearborn Chemical Co. of Chicago.)

Cleaning Material:

Clean, sharp, dry, silica sand, passing 16 mesh screen.

Coating and Cleaning Equipment:

Steel Filter Tanks and Valves:

- 2½x7¼ in. Osborn Master Wheel wire scratch brushes.
- 6 in. diameter Osborn air power brush.
- 3 in. Red Devil wall scrapes.
- 1 Linde W-26 ox-weld-acetylene flame priming torch and equipment.
- 1 Ilg Electric 400 c.f.m. exhaust fan.
- 1 Westinghouse Electric 2,000 c.f.m. exhaust fan.
- 1 Homelite gas motor, 2,000 c.f.m. exhaust fan.
- 1 Buffalo Forge Electric 1,200 c.f.m. exhaust fan (sand blast cabinet).

Material Application Equipment:

- 5 gallon capacity kerosene burning torch.
- 1 ½ in. natural gas-air burning torch.
- 1 gallon capacity Universal electric hot material coater.

Miscellaneous Material:

- 1 25 H.P., 115 cu. ft. Gardner-Denver air compressor.
- 1 5 H.P., 25 cu. ft. Curtis air compressor, portable.

GENERAL DATA ON QUANTITIES

	Man Hours			Thickness of Coating	Pounds Coating Material*
	Cleaning	Coating	Repairing		
Metal Filter Tanks (per 1,000 sq. ft.)	80	36	...	1/16"	107
Concrete Walls (per 1,000 sq. ft.)	58	20	...	1/32"	75
24" Hydraulic Valves (per unit)	11	1	4	1/32"	2
Miscellaneous Valves and Fittings 8" to 18" (per unit)	4	½	¾	1/32"	1½

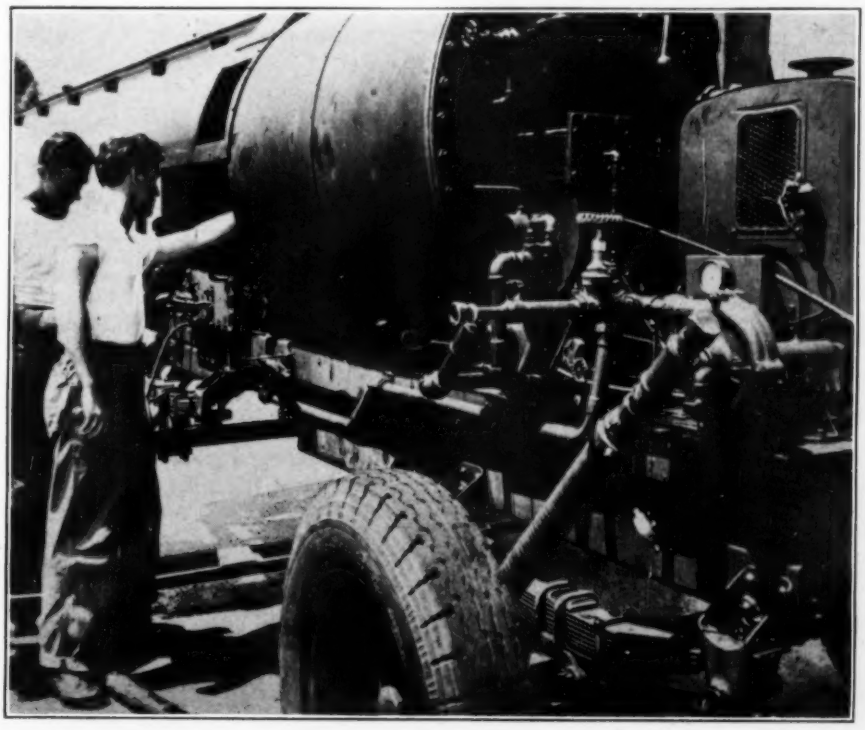
*For all but the hydraulic valves the material used was "No-Ox-Id XX"; for the hydraulic valves "No-Ox-Id A-Special" was used.

A Leatherneck Water Purification Unit

The accompanying picture is of one of the field water purification units of the U. S. Marines.

Authorization to publish this picture has come through Major John V. Sandberg, U. S. Marine Corp Public Relations Officer, who writes: "Water purification is considered a big factor in maintaining the health of our fighting leathernecks, both in training and combat areas. To this end special details are trained in this important work ot the Marine Corps Water Purification School on the West Coast."

Perhaps what is the toughest problem tackled by the Marines has been that of taking dirty salt water and turning out a supply of potable water. Until recently nothing short of distillation could solve this problem.

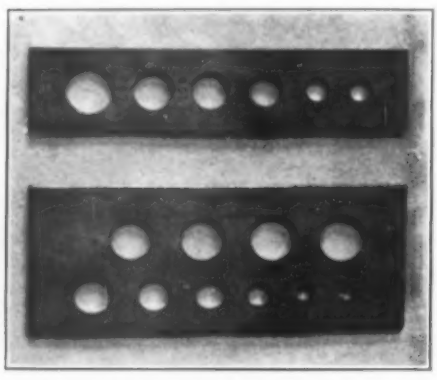


A GAUGE FOR METER CHANGE GEARS

By DON. C. CALDERWOOD
Engineer
PENNICHUCK WATER WORKS
NASHUA, N. H.

YOU may find the following gadget useful in your meter repair shop. This probably will be especially true if due to war conditions you have had to replace at least a part of your trained meter repair crew with men of less experience and ability.

Of necessity most meter repair shops carry a good stock of register and spindle change gears and regardless of make most of these gears look very much alike. Most water departments also use several different makes of meters and no matter how hard you try to keep these gears separated and in the right place they get mixed up as to size, make, and number of teeth. A trained man with a micrometer and the manufacturer's specifications can separate and properly sort out these gears, but it is a time consuming job.



Meter Change Gear Gauge

In order to facilitate this sorting, to keep our stock in order, and to assist in the meter repair work we had a set of gauges made, each gauge applying to one make of meter. A gauge consists of a piece of brass plate (nearly any metal will do) with holes drilled to the exact diameter of the change gears used in that make of meter. For example, we have several hundred "Watch Dog" meters which use change gears of the following diameters.

TABLE I—"WATCH DOG" CHANGE GEARS

Meter size	Gear Diameters—Register	Gear Diameters—Spindle
⅝"	.847"	.490"
¾"	.805"	.705"
1" & 1¼"	.522"	1.000"
1½"	1.000"	.522"
2"	.805"	.705"

The Author

Accordingly we had a gauge made with the holes of the above six diameters bored through the metal and properly stamped with the name of the meter and the diameter of each hole—see cut.

Some meters, such as the Hersey, use a slightly different system. Hersey change gears of more recent manufacture are stamped with a letter that indicates the outside diameter, but some of the older gears are not stamped or the markings are obliterated so the following table was made.

TABLE II—HERSEY CHANGE GEARS

Meter Size	Model	Gear Diameters—Spindle		Gear Diameters—Register	
⅝"	F	B	.312"	X	1.008"
¾"	D, HD, FF, HF	E	.394"	V	.937"
¾"	F	K	.541"	W	.979"
¾"	D, HD, FF, HF	P	.703"	S	.815"
1"	F, D	S	.815"	P	.703"
1"	FF, HF, HD	U	.875"	N	.645"
1¼"	D	U	.875"	N	.645"
1½"	F, D, HD	E	.394"	Z	1.125"
2"	D, HD	K	.541"	W	.979"

In this case we took another piece of metal and bored eleven holes to exact size and stamped not only the diameter of the hole but also the letter indicating the diameter.

These are merely two examples of how this problem can be handled. It goes without saying that you should limit your gauges and diameter of the holes so that they apply only to the make, size and model of the meters you are using. The information and data concerning the diameter of the change gears is probably in your files but should the information be lacking, the manufacturer will gladly supply you with it.

In making up your tables of diameter combinations for the various sizes and makes of meters you can carry it to any degree of refinement you wish. Originally our tables consisted only of the diameters of the gears and the combinations as listed in this article but more recently we have revised it to include the usual number of teeth on each gear to obtain the correct registration and the various number of teeth obtainable in a gear of any given diameter.

Like many new things the older employees rather laughed at the need of such a set of gauges, but now they freely admit that it speeds up the repair work and is a vast improvement over the old system.

In regards to the gauges themselves they are not hard to make, but we were fortunate in that they were obtained at no cost to us. There is a local school training men for jobs in defense plants and the instructor of machine shop was glad to have one of his pupils do this work as part of his training. The purpose of this article is only to give you the general idea so that you can change and adapt it to fit your own needs.

"Scot" Highland Says Clarksburg Once Again Safe

J. R. Romine, up for re-election to the Clarksburg, W. Va., Water Board, was defeated in the recent election. His successor is Robert Morris.

Scotland G. Highland, Secretary, Treasurer, Engineer and General Manager of the Clarksburg Water Board, says that Romine was a New Dealer, while Mr. Morris is a Republican and a gentleman. Thus ends nine years of headaches for "Scot" Highland and the other members of Clarkburg's Water Board—now 100 per cent Republican.

N.E.W.W.A. HEARS U-1 ORDER INTERPRETED

Holds Open Discussion On Post War Plans

AT ITS regular May meeting in Boston on May 20th, the New England Water Works Association heard what is believed to have been one of the most lucid interpretations of the muchly discussed and cussed U-1 Order of the Office of War Utilities which has been given by anyone to date. The interpreter, who has had considerable contact with the Power Division of W.P.B., was R. J. Daniels, General Storekeeper, New England Power Association Properties. Along with his analysis he reviewed the proposed workings of the new Regional Utility Inventory Control offices now established by the W.P.B. throughout the country. His remarks were suppplemented by Ralph E. Waters, Regional Utility Engineer from W.P.B.'s Boston office, who discussed the scope and method of operation of the Utilities Inventory Control Office. Following these interpretations and explanations many questions directed from the floor were answered by these gentlemen in a highly satisfactory manner, which served to clear up numerous questions in the minds of water works managers and others interested in an order which appears to be overly and probably dangerously restrictive in respect to water utility inventories and the maintenance, repair and replacement programs which have been permitted to lag as a part of the water works operator's contribution toward reduction in civilian use of critical materials.

Forenoon Session on Post War Plans

(E. Sherman Chase—Chairman)

Interest of members in advance planning of post-war activities and betterments to water and sewerage systems was evidenced by the packed meeting room to hear the recently issued preliminary draft of the Association's Committee on Post-War Activities briefed and then presented for open discussion by the chairman —E. Sherman Chase.

The report, in review, points to the following considerations in getting ready for post-war activities in the water works field.

In general, planning for post-war activities in the water works field should have local and specific benefits as the primary objective. Individual responsibility needs to be stressed now more than individual rights. Centralized Federal controls should be reduced to a minimum and

Vice-President
Horace L. Clark
Sanford, Me.
(Acting President)

Chairman
E. Sherman Chase
Boston, Mass.
(Discussion Leader)

dependence on federal subsidies should be given up where not absolutely essential. Local self-government should prevail in local problems. Local communities should look ahead and plan to prevent or reduce unemployment at the close of the war, and water works men should play their part in the alleviation of post-war problems.

In a "Program for Water Works Officials," the report suggests that,

State Sanitary Engineers

Warren J. Scott—(Connecticut)

Arthur D. Weston—(Massachusetts)

Clarence E. Ferry—(New Hampshire)
(Secy. New Hampshire Water Wks. Assn.)

above all, employees returned from the armed services should be restored to the payrolls insofar as practicable. Investigations of the condition of water works systems and maintenance work should be resumed. Reinforcements of the system, cleaning and relining mains, and replacement of undersized mains should be undertaken to improve water distribution.

Scrapping of obsolete mechanical equipment as well as obsolete office systems is desirable and records should be brought up to date. Complete and accurate maps should be provided. Waste water surveys, metering programs, reforestation of watersheds, and sanitation work on watersheds are practices that not only help to conserve a vital resource but also improve the product and the service rendered.

In a "Program for Manufacturers," it is also recommended that former employees, now in the military service, be returned to work. Expenditure of monies for research and the investigation of new designs, materials, and equipment are highly desirable. Present products should be improved and the possible use of new materials, such as the plastics, should not pass unnoticed.

It is suggested that chemical companies and manufacturers of construction materials should be educated to the special needs of the water works field and encouraged to improve products. Tests on new developments should be carried out to eliminate the inevitable early difficulties, before the development is offered to the field.

As a program for the New England Association, it is suggested that an educational campaign be inaugurated to assist in the carrying out of the above suggestions, and this campaign should include papers and discussions on post-war activities.

It is also recommended that current water revenues in excess of current needs be used for water works improvements. Federal grants should not be accepted where ample financial resources exist and bond issues should be used as sparingly as possible.

It is highly important that a superintendent or manager should begin to educate his commissioners or board now, securing the cooperation of State Board of Health, newspapers, veteran organizations and labor unions.

It seems essential that much of the preliminary ground work and planning be done before the war's end.

In addition to the Chairman the Committee consists of Theodore Cate, Harold W. Griswold, Phil J.

Holton, Howard H. Potter, Fred J. Reny and E. L. Tracy.

Discussion

The chief purpose of the meeting was discussion of the report and Chairman Chase called on members

Discussors

"Sid." S. Anthony
Superintendent
Augusta, Me.

Fred J. Reny
General Manager
Portland, Me.

for comments which included the following:

Arthur D. Weston, Chief Engr., Mass. Dept. of Health, of the opinion that local governments were expecting another Federal handout for public works after the war, felt that preparedness in advance by the water works folks (and readiness to go) would be an essential requirement if water betterments was to receive the attention for which the better roads interests are striving and very likely to get unless the voice of water and sewerage authorities is heard louder than has been heretofore the case. The importance of water supply betterments and expansion must be stressed at home to create a local demand for such. This meant publicity and advance education.

Walter J. Shea, Chief Engr., R. I. Dep't. of Health, said that water betterments were easier to sell the local authority on than sewerage improvements. He saw the need for water works men on every Planning Board.

Warren J. Scott, Chief Engr., Conn. State Dep't. of Health, thought that the committee recommendation of survey making and mapping should be for the present rather than a post-war activity. His idea is that the committee should be expanded for the purpose of making a real survey for concrete potential post-war improvements with particular consideration to readiness to go. He felt that the Association should take a more effective part in education of the public as to the investment value of adequate water supply facilities planned in advance of immediate needs.

Horace J. Cook, Sup't., Auburn, Me., made the practical suggestion that orders for equipment and materials should be made up at present and placed with the manufacturers, with understanding that such orders be filled as promptly as the war demand ceases. Thus the manufacturers could do more advance planning on their own and keep the workers employed. The same reasoning applied also to financing of projects and bond issues could much more advantageously be sold today than after the war.

Fred J. Reny, Genl. Manager, Portland, Me., Water District, also spoke on the desirability of advance financing or re-financing on the present cheap money market because it was to be expected that interest rates would be much higher in the post-war period. The Portland Water District, for instance, had just refunded about 33% of its high interest bonds for 20 year bonds at a rate one-third that of what might be termed normal. This reasoning applied to small as well as large cities. An ardent believer in publicity and its worth to the local water utility, Mr. Reny pointed out that a good start can always be made by asking consumers to make suggestions looking to better service and economies.

Wm. B. Duffy, Sup't. of Public Works, North Andover, Mass., made the splendid suggestion that the Fire Underwriters be called upon to survey local water systems for the purpose of setting up a program of improvements which might be prosecuted in the post-war period but gotten ready for immediately. In North Andover the work now scheduled to be done far exceeded what had been anticipated in the way of improvements.

Roger Esty, Sup't. of Water and Sewerage, Danvers, Mass., reported that Danvers has one and a quarter million dollars in projects planned, including a filtration plant, water mains and new sewers. Danvers has an impounded fund, constantly growing, and ready for post-war betterments. He had been preaching to his Board to have plans ready to go.

Sidney S. Anthony, Sup't. Augusta, Me., reported the accumulation of surplus water funds in Victory Bonds looking to post-war improvements. However, he was of the opinion that water works managers should consider the matter of overall costs and not proceed too hastily if prices for materials and labor appeared fictitiously high, which might prove the case in a brief post-war boom.

W. W. Brush, Editor, "Water Works Engineering," told of the New York law, in which the State pays 50% of the cost of post-war plans to a community. He suggested that manufacturers' representatives could assist superintendents in planning betterments by telling them what their systems needed most.

Joseph F. Cairnes, F.W.A. engineer, urged water works managers to have their plans in shape as soon as permissible so that other public works would not get ahead of water supply and sewerage in the allocation of whatever funds were to become available, either locally or nationally.

Sam Ellsworth, Cons. Engr., raised the question of whether we shouldn't keep to the job of winning the war and the peace first and not be thinking too much about planning toward a post-war fictitious prosperity. And Major Howard Potter, O.C.D. Regional Engineer, in considering costs and availability, suggested that it was highly probable that the now critical materials would experience an unprece-

(1) (2) (3) (4) (5)

(1) *"Bill" Johnson, Pres. Phoenix Meter Co., N. Y.*

(2) *Alan J. McAlary, Supt. Rockland, Me.*

(3) *Roger W. Esty, Supt. Water & Sewer Board Danvers, Mass.*

(4) *G. L. Winslow Water Bd. Auburn (Me.)*

(5) *Horace J. Cook, Supt. Auburn, Me.*

dented demand, remain hard to get and expensive beyond normalcy for some time after the war's end.

The U-1 Order

The afternoon session was devoted entirely to the muchly discussed (and cussed) U-1 Order of W.P.B.'s War Utilities Office and the policy and functioning of the new Regional Utility Inventory Control Offices.

R. J. Daniels, General Storekeeper for the New England Power Association properties, a member of W.P.B.'s Special Power Advisory Committee, did an outstanding job of analysis and interpretation of the order in terms understandable to others than the corporation lawyers responsible for needless obscurity and legalistic terms which make more jobs for more and more lawyers and more and more confusion in the intended workings of what should be the most simple document possible.

Mr. Daniels began by explaining that the P-46 Order and the supplanting U-1 Order were produced principally to protect inventories (supplies on hand) of indispensable utilities from raiding by any Federal authority even including the Army and Navy. The controlled Materials Plan (C.M.P.) was developed to insure the availability of raw materials and unfabricated products to manufacturers on a predesigned schedule. In these steps the Power Division had the services of key men from the utilities field who knew no work hours while in Washington or elsewhere.

Mr. Daniels struck a bull's eye when he stated that it was important to know the real meaning of terms employed and definitions of words used in the order. His first "A.B.C. Lesson" in U-1 was to define the most important words and terms as follows:

Material: Everything used by a utility which can be seen or felt. Therefore, "materials" included pumps, engines, motors, trucks, etc., as well as packings, pipe, chemicals and coal.

Inventory: Inclusive of equipment and items (materials) *not* at the minute installed for immediate use. For instance, a pump not bolted down is an inventory item.

Accounting: Is in reality statistical records, rather than true accounting.

Supplies: Includes all of the smaller items and embraces materials used for minor extensions of services not of a size to be classified as construction.

Extensions: Are improvements or additions *of any sort* permitted under the limitation of $1500 for materials and supplies required in underground construction or $500 for new above ground construction, additions or replacements.

MRO-U: Is the symbol used for Maintenance Repair and Operations on an order as good as a C.M.P. number. Above the prescribed limit of new materials plus inventory to be used, an M.R.O. order must have special approval from Washington on one of the 13 Regional W.P.B. Offices.

P.W.M.: Signifies "practical working minimum."

Quarter Quota: Concerning the need for not exceeding permissible withdrawals from inventory and/or new purchases for any given quarterly period, the U-1 amendment of April 17, 1943, permits a utility to exceed the quarterly limit so long as the calendar year is ended without exceeding the present allowance of "four thirds" (1.33) times the value of materials of that *same class* which were used in the last 9 months of 1942. Any deficiency in use of materials in any previous quarter can be taken as a credit against over-use in the succeeding quarters of that same calendar year.

In regard to possible necessity for exceeding the year's quota Mr. Daniels suggested filing application for permission to use materials to the extent of 60% of 1940 use—the quota allowed under old P-46. Indications are that the revised U-1 order now in process of development will not be so strict, and more in line with the quota of P-46. He warned against asking for more than the old 60% of 1940 quota without exceptional grounds. He also stated that the revised order will reduce red tape and need for letter writing.

Discussors

Walter J. Shea
State San. Engr.
Providence, R. I.

Wm. B. Duffy
Supt. Public Wks.
North Andover, Mass.

Sales of Surplus Inventory: Is mandatory to other utilities requesting such. To contractors who can show an AA-3 rating or better surplus *can* be sold but is not mandatory. Since voluntary disposal of inventory surplus has not yet proved to be practical, it had been necessary to establish in the War Utilities Office an Inventory Control Section with representatives in 13 W.P.B. Regional Offices.

The Inventory Control Plan

Ralph E. Walters, Engr. in Charge, W.P.B. Regional Inventory Control Office, Boston, who at this juncture was introduced, outlined the policy and plans of the new Inventory Control Section. He complimented the water works managers of New England and State Water Coordinators on the lead taken in inventory survey work, recording and mutual aid programs. The status of the water utilities probably accounted for the fact that his staff contained no water supply engineer.

In respect to making purchases from manufacturers such would only be permissive when the same class of materials were not available from the surplus stocks of other utilities in the region. Even

(1) (2) (3) (4) (5)

(1) *"Bob" (R. W.) Fergusson, Hersey Meter Co.*
(2) *John C. Knox, Engr. Mass. Dept. of Health*
(3) *Sam. Ellsworth, Consulting Engr. Boston*
(4) *A. B. Thompson, Supt. Waterville, Me.*
(5) *E. H. Lewis, Pres. Tate Pipe Linings, Andover*

then the Regional Control Office will try in other states to find the needed items or materials. If not successful an AA-1 rating can be applied to an order placed direct with the manufacturer. After material is located the prospective purchaser issues an order to the utility having the surplus using the same AA-1 rating and dealing direct rather than through the Regional Control Offices.

Any orders for new M.R.O. materials which totals $100 or less can be placed direct with a manufacturer or jobber under AA-1 rating, without approval of the Regional Control Office.

Questions and Answers

In reply to questions from members the following opinions were given by Messrs. Daniels and Walters:

(1) What the eventual disposition of the frozen copper in water and electric utilities' stocks will be is a question. In the final necessity it will be taken for reworking at a ceiling price ruled by the O.P.A. as equitable. This is to be avoided if possible.

(2) A water utility can supply the materials to replace a service line or lay a new one into the consumer's property up to the meter and collect the costs from the consumer. This naturally is contingent on the permissibility of giving service to properties not hitherto having such—i.e., only to properties already piped for water service. (This is in parallel with the permissive installation of electric or gas service.)

(3) To give a new service line of any nature to any property without piping prior to July 1, 1942, or without foundation completed by that date is not permitted without a special permit under the L-41 order.

(4) Where two properties have been served through a common service line it is not permissible to install a second line so as to give each individual service. Permission if applied for will be hard, if not impossible, to secure.

Wm. E. Tracy, Secy.
Bristol (Conn.) Water Bd.
and
Frank J. Theiry, Supt.
Bristol, Conn.

"Sid." Anthony, Supt.
Augusta, Me.
and
Arthur Burke
A. F. King & Co., Boston

Chas. L. Lynch
New England Rep.
and
Wm. H. Johnson, Pres.
Phoenix Meter Co.

Expert Official Recorder

Raymond M. Kinsman—Boston

(For many years official recorder and reporter of N.E.W.W.A. proceedings, has come to be a land-mark at its meetings. This candid shot caught a characteristic pose during a discussion.)

Maine Ass'n. Issues Special Interpretative Bulletin on U-1

Before sounding off with this report it is desired to call attention to the very excellent Bulletin No. 3, recently issued by the Maine Utilities Association as a clarifying brochure for members having to interpret and operate under the amended U-1 Order of April 17th, 1943. This worthy bulletin was prepared by the M.W.U.A. Defense Committee. If interested, the reader *may* be able to secure a copy from the Association by inquiry to Horace J. Cook, Defense Committee Chairman, Supt. Auburn Water District, Auburn, Me.

"Bill" Highberger—U. S. A. Reported Missing

A brave little woman, two sons and a host of friends anxiously await some further news of Lieutenant William W. Highberger, Chemical Warfare Service, U. S. Army, who has been officially reported as "missing in the Western European War Area" since early February.

"Bill" Highberger, before entering the service, was a salesman with the Mathison Alkali Works, who exhibited a never-failing enthusiasm in his work and genuine interest in the welfare of his many friends. He was a welcome visitor wherever he went and was held in the highest esteem by water works and sewerage men with whom he fraternized because he was so well liked by this group.

"Bill" was a native of Greensburg, Pa., and a graduate from Lafayette University (1927), where he made a niche for himself on the gridiron and as a swimmer. For some time his home has been in Mt. Vernon, N. Y.

"Bill's" first thought seemed always to be for his fellow-man, and if he has died in the service of his country, it is more than probable that he gave his life trying to help someone less fortunate than he.

Like all of the friends "Bill" Highberger has, we hope that he will return to us some day and that he is really only missing and has not joined his fellow countrymen of Flanders Field, World War I.

Velzy to Manage New Greeley and Hansen Office in New York

Greeley and Hansen, Consulting Hydraulic and Sanitary Engineers of Chicago, have recently opened an office in New York City at 299 Broadway. The new office will be operated in connection with construction of sewage plants in the metropolitan area. Mr. Charles R. Velzy will be in charge and will come to New York from Norfolk, Va., where he has recently been in charge of work on the sewage disposal problem of that city. Mr. Velzy was consultant to the Army Quartermaster Corps, in which capacity he designed the sewage treatment plant for the War Department Pentagon Building. Prior to that activity he was Works Superintendent of the Buffalo, N. Y., Sewage Treatment Works. Greeley and Hansen were consultants on the aeration design of the Ward's Island treatment plant in New York a number of years ago.

REJUVENATE WITH "VICTOREE LINING"

A Story

By ROGER W. ESTY
Superintendent
DANVERS WATER & SEWER BOARD
DANVERS, MASS.

The Author

AS MAN grows old, it is quite natural that nature affects his blood flow-lines to such an extent that it causes the heart to pump with greater difficulty against a friction which grows with age. The result from such a condition is recorded in terms of blood pressure. This circumstance, in a measure, may be compared with what we find going on in a water distribution system, which is, after all, "the arteries of a city." Tuberculation creeping in yearly makes it more difficult to pump water through such "arteries" at the same speed or velocity as earlier, so we have to increase the pressure of the pumping station ("the water department's heart") to secure the same delivery at the end of the line that was obtainable in its younger days under lower pumping heads. In addition to greater wear and tear on "the water works heart," it also costs money to pump against that additional head. The condition can be overcome temporarily by mechanical cleaning of the mains, but tuberculation (arterial sclerosis of the mains) is found to grow faster after the cleaning than it originally did. Why not go one step further, then, than mechanical cleaning alone and put in a protective lining which makes of this rejuvenation process a permanent job?

One Secret of Success.
The important mortar condition slump test.

And Now My Fellow Sufferer—

If you are really interested in doing something worthwhile to overcome permanently this old age condition in *your* system, get comfortably seated, light up the good old pipe, get your feet placed in a comfortable position, adjust your glasses (if you have joined us old-timers), and read this article. If you are not interested in making a real investment for your city or town, then just skip this article and turn to the next one, as I don't want to waste any of your valuable time.

All right, let's get going! My suggestion is, let's rejuvenate our older water mains by lining them in the ground, without taking them out. This can be done today by a proven process of putting in an everlasting protective cement mortar lining.

Many systems today have mains and service pipes that are 75 years old, and right here in Danvers, Mass., we still have a few miles of the earliest cement lined street mains ever to be laid, and several miles of cement lined service pipes that were laid in 1876, and still giving good service.

The Job Under Way.

The 7/16-in. flexible steel rod is just pushed through the old tuberculated main. Then follows the ⅝-in. cable which is winched through wtih cutting tools and scraping discs on the end.

Charging the mortar through the vertical riser with long sweep bend at base connected to main with Dresser coupling. The mortar in the pipe, the lining mandrel is winched through to uniformly coat the pipe and compress the lining.

The Array of Equipment Used on Our Danvers Job

What I am terming "Victoree Lining," because of the fact that it does not take many men and requires only about 5 per cent of the critical materials that main replacement would involve, is not costly, nor does it deplete your shrinking inventory.

You may ask, how much work does it require on the part of the water department personnel to do this lining job? Generally this kind of work is a contract type of a job. There is the Tate process for small mains and the Perkins and Gillespie (Centriline) process for 30-inch mains and larger. Each have their own particular methods and neither apply to both large and small diameter pipe lines.

Danvers' Experience

We have lined about 12,000 feet of 6 and 8-inch cast iron mains within the Danvers' system and, unless we are temporarily delayed, while you are reading this article we will be in the midst of lining an additional 6,000 feet of 8-inch cast iron main.

I got interested in this method of lining in 1939 when we had a condition arise wherein the water in a certain area was so unpalatable that the consumers complained that they couldn't use the water and had to bring in their drinking water from another section of the town.

We called in the State Department of Public Health to take samples for examination and analysis, and advise us as to the unpalatable condition of the water and as to how it might be corrected. From their inspection they found the following conditions at a certain house, as compared to the water at our pumping station:

Location	*Color*	*Iron*	*CO_2*	*PH*	*Dissolved Oxygen**
Lake Pumping Station	45	25	2	6.9	89
House in question	55	85	6	6.7	6

*Per cent saturation.

After this pipe line had been lined with cement mortar and a thirty day period had elapsed, we had the following results from an analysis:

Location	*Color*	*Iron*	*CO_2*	*PH*	*Dissolved Oxygen**
House in question	33	.14	0	9.1	36

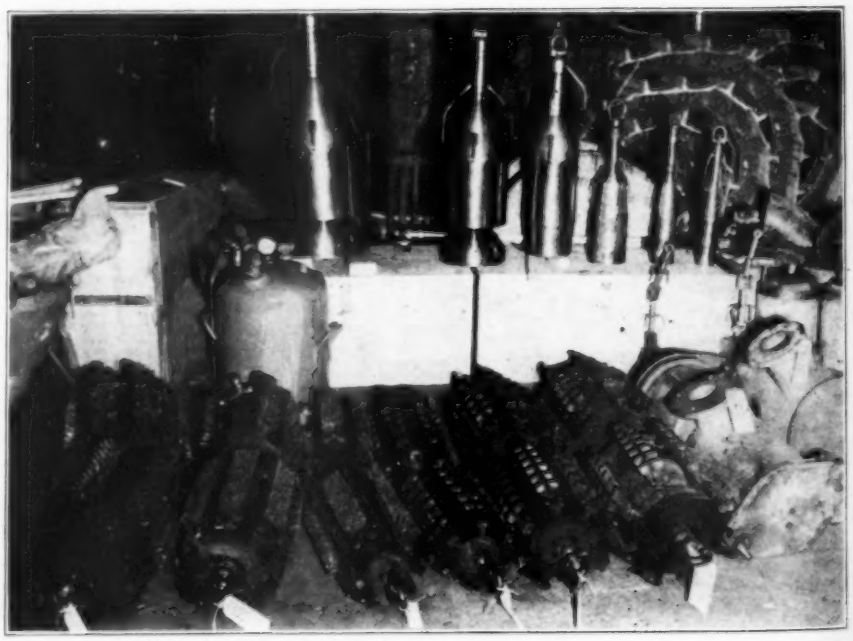
*Per cent saturation.

With the exception of one complaint on hardness (shortly after lining) we have not had any further complaints.

The following is extracted from the first report of the Massachusetts Department of Public Health: "In the opinion of the Department, the condition of the water as supplied to the premises at 26 Clinton Avenue and at other premises in this vicinity is due for the most part to the decomposition of microscopical organisms and other organic matter in the distributing mains, particularly near the dead ends. The decomposition results in the formation of carbon dioxide gas and corrosion of the mains. This condition is accentuated by the length of time that the water stands in contact with the unlined street mains, particularly in dead-end pipes similarly located."

Means of Correction

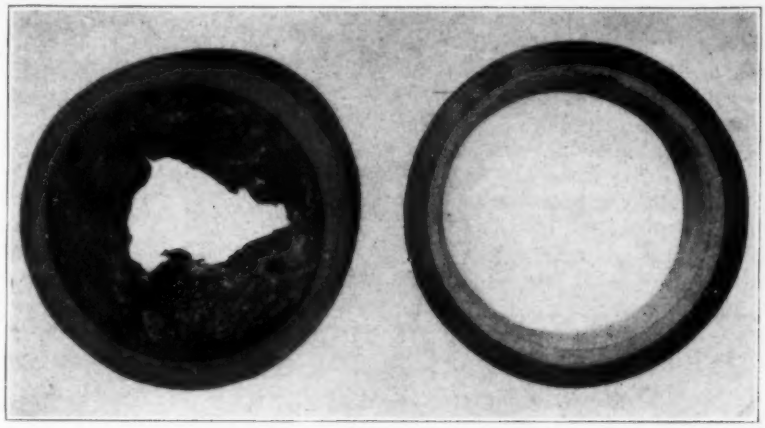
The Department recommended flushing and that a bleeder be installed at the end of the line. Such a bleeder was installed and a water meter was placed on the line to regulate the flow. By operating a valve at the meter, the flow was so regulated that the line would be replenished with fresh water about three



A Closer View of the Various Sizes of Scale Cutters and Cleaning Brushes. On the Boxes Are the Several Lining Mandrels—4 to 12 in. Sizes

to four times every 24 hours. The bleeding did correct the iron and the low dissolved oxygen and high carbon dioxide gas condition to a certain degree. This method of helpfulness to the consumers was not, however, considered permanent or economical. There were three ways of correcting the condition, some permanent and some temporary. (1) We could lay a new pipe with a protective lining. (2) We could let the water run continuously. (3) We could line the cast iron pipe in the ground with cement mortar.

We chose the lining process. It has proven most satisfactory, not only in improving the quality of the water from an analytical basis, but naturally has improved the fire flow and service pressures permanently.



Which Main Would You Prefer?

That on the left, suffering from arterial sclerosis with high pump pressure and low hydrant pressure, is in addition a repository for decaying organic slimes and oxygen depleting organisms. Result: Tastes, odors, iron, and pressure deficiency. On the right a smooth, joint-filled continuous tube which does not suffer from "dead-end halitosis."

The Tate Method of Cleaning and Lining

The method of doing this work is briefly outlined in the following paragraphs:

We awarded the contract to the Tate Pipe Linings, Inc., of Andover, Mass. They furnish all of the necessary equipment and mix up the cement mortar and place it in the pipe. The Water Department can have them do all of the excavating, but this time we are doing all of the excavating and cutting of the pipe lines, and the reconnecting and back filling, with our own men and with four or five extra men.

Every gate valve has to be dug up as well as every hydrant or street tee, all crosses, all bends and every house connection. This sounds like a lot to do, but like most jobs, the planning always seems like the hardest part of the job and we oftentimes worry about things that never happen.

Preparation and Cleaning

After a temporary two inch line is laid along the gutter to connect into all of the house services, the excavating of all fittings and corporations takes place. The pipe is cut out in two places at gates and tees, if they are close enough together, or somewhere at a service corporation. After the two pieces have been taken out, the contractor runs a 7/16" flexible steel rod from one hole to the other (see picture). He then connects on a 5/8" steel cable which he draws back through the pipe. The cable is attached to a winch mounted on a truck. Trucks with winches are placed at each hole to draw this cable back and forth with the various cleaning devices and lining attached to it. First heavy scrapers are dragged through to break off the tuberculation. Then wire brushes with rubber squeegees are dragged back and forth to clean off the balance of the tuberculation which is scraped out by the squeegees. This is repeated if necessary. Then a solid metal "proving plug" is dragged through to make sure there are no obstructions, such as a forgotten corporation, blisters on the pipe, spigots of pipe not centered in the bells, and also to see that the pipe is round, and not mis-shapen. If this goes through, then we know that the lining machine (mandrel) will go through and will not get stuck.

Mortar Mix —

A vertical loading pipe is then set up at the end of the pipe in the ground and connected to the water main by a Dresser coupling. While this is being connected up, the mortar bed is set up and the amounts of sand and cement, consisting of 2 parts sand and 1 part cement, are placed in the mortar bed and thoroughly mixed. All sand and cement is screened and great care must be taken in selecting the proper kind of sand. The distance to be lined is carefully measured and then the required amount of materials are mixed, with a slight surplus as a safety factor, this to assure a sufficient head at the end of the pull to get a good lining to the very end.

After the mortar is mixed and the important slump test is made on the mortar, it is then placed into the upright pipe and worked into the water main by drawing the cable slowly through the mortar. Then a squeegee (plunger) finally forces it down and out of the upright pipe to where the connection is made by a Dresser coupling with the pipe in the ground. The charging pipe is then disconnected and the lining machine (mandrel) is connected to the cable and the winch gradually draws it in and along through the pipe. The bullet shaped mandrel is drawn through the pipe at about 4 to 5 feet per minute. Various mortar slump values are reproduced to best suit in the lining of various lengths of pipe. When lining a run of 350 to 400 feet, a slump of 8 to 8¾ inches is required.

The Completed Job

A 3/16 to ¼ inch lining is the customary thickness, and this compressed to the walls makes a permanent protective coating. The section lined can be connected up and put back into service in about 24 hours. Plugs are placed in the corporation openings while the lining process is going on, and after these are removed and the cement reamed out with a knife, the corporation is then inserted. All fittings are then connected back into the line with Dresser couplings.

We know that cast iron pipe is a very durable material, and there is cast iron pipe in Versailles, France, that was laid between 1664 and 1688 and still in service. So you can readily see that with a material such as cast iron, with a cement lining as a protective coating, you have as near a permanent pipe line as can be possibly obtained.

I wish to quote Mr. James E. Gibson, Manager and Engineer of the Charleston, S. C., Water Department, on increased carrying capacities. "However, in one case we did measure the diameter of the main after cleaning and determined the value of

"C," which in this particular case was 140. This was a 4-inch pipe with actual inside diameter of 3.36 inches after lining, the reduction in area being 29.6 per cent. The actual discharge through the 4-inch main before lining was 130,700 gallons per 24 hours with a loss of head of 67.3 feet per 1,000 feet of pipe. After cleaning and lining, with a loss of head of 66.8 feet per 1,000 feet, the delivery per 24 hours was 316,400 gallons, or an increase in the delivery capacity of 240 per cent."

That statement alone should be sufficient evidence of the value of lining mains with cement mortar. Further along in his published paper in WATER WORKS AND SEWERAGE he shows that he lined over 12,000 feet and that the improvement in the carrying capacity ranged from 210 to 280 per cent.

The Overall Benefits

Summing up the benefits derived from this work, we find there are many points which make this a very inviting type of work for the use of available funds during this war period when there is little opportunity to make other improvements. The following are some of the advantages derived from this type of work:

1. The cost of rejuvenation only one-quarter to one-third that of a new pipe line.
2. It provides a permanent protective lining.
3. It increases the carrying capacity of the mains up to two and three times that of the old tuberculated main.
4. It can be done with a small crew of men.
5. It requires very little critical material.
6. It practically eliminates all bacterial conditions in sluggish flow areas.
7. It makes the water more palatable and satisfactory for various uses.
8. It covers up all bacteria harboring joints and provides long runs of 300 to 600 feet, making a continuous concrete tube.
9. It reduces pumping head and pumping costs.

Now this is something that all of us can do that have old cast iron mains that have been gradually filling up. Let's line our pipes now. Just as surely as we are going to lick the Axis for all time, here's something that will lick deterioration and corrosion for all time too.

Let's call it during these war times, "Victor*ee* Linings."*

[*With apologies to radio's Gracie Field and the Editor of "Water Works and Sewerage."]

METER MAINTENANCE DURING WAR TIME

By E. T. CRANCH
DIRECTOR OF PUBLIC WORKS*
NEW ROCHELLE, N. Y.

SHORTAGES of labor and material have affected meter maintenance along with almost every other field. It is well to consider ways and means to reduce the labor and materials used in meter maintenance. Some municipalities still follow the practice of not removing a meter for test or repair until it stops. This procedure undoubtedly reduces the use of labor and material to a minimum but it is not a practice to be recommended even in wartime. The other extreme is where the time of removal of a meter is fixed by regulation of a Public Service Commission. Unless the regulations can be changed, little economy can be effected in the removal of meters under such circumstances, except by carefully routing the trucks used in this work so that there will be no unnecessary mileage. Also men going out on other jobs can often change meters along the route they follow.

While a maximum interval of five years between tests seemed a reasonable requirement during ordinary times, it would not be unreasonable, during war times at least, to lengthen this period to seven or even ten years. This method would mean a considerable saving in labor and material.

Testing Without Overhauling

Assuming that it is not desirable to change the regulations, then the times of testing can remain the same but the time between overhauls can be lengthened. It is common practice, and good practice, to overhaul every meter that comes into the shop no matter how well the test before repair turns out. This method insures the highest quality of meter operation. But during war times the period between overhauls can be lengthened. For instance, every meter that has been in for less than four years and passes the test before repair can be put right back on the shelf ready to be sent out again. This method will produce a real saving in labor and material on those meters brought into the shop for other reasons than for routine tests —for instance, those meters brought in from closed accounts. The result will be that there may be a maximum of nine years between overhauls on some meters. As it has been the experience of several meter shops that about half the meters brought into the shop are brought in for reasons other than for routine test, it can be seen that a real saving will result by not overhauling those meters passing the test before repair and which have not been in service over four years.

Some recommend that this procedure be applied also to those meters brought in for the five year routine test, advocating that any such meters passing the test should be put back into service without overhauling. The writer, however, is not quite willing to subscribe to this. While he is willing to see concessions made for the benefit of the war effort, he still believes the best practice is to overhaul every meter coming into the shop, and that any shop deviating from this practice should return to such practice as soon as possible after the war.

Materials Savings

In the actual repair of meters little can be done to reduce the use of material. If the bottom gasket is still in good condition, it can sometimes be used over again. But if it is not in the best of condition it is better to use a new one, for otherwise a leak will surely develop. In meters equipped with built-up discs the disc spindle can often be salvaged and sometimes the balls can be built up to a close fit by use of paper inserts, thus avoiding the necessity of putting in an entirely new disc. In any case, a close fitting disc will register accurately over a longer period than a loose fitting disc.

At all times it is the best economy in overhauling a meter to do a careful and complete job. A careless meter repair job has never been worthwhile.

*Until his recent appointment, the author was for a number of years General Manager of the New Rochelle Water Co.

Metering in Wartime . . .

Simple as A B C

DON'T REPLACE WHEN YOU CAN REPAIR!

A Our country's interests come first. Conserve as you serve by making your present meters last for the duration. Institute an immediate program of inspection, repair and maintenance.

REPAIR METERS THOROUGHLY! TEST CAREFULLY!

B Good meters require but little attention. When they are renovated, do a complete job. A properly repaired meter should test as good as new. The cost of a thorough overhaul is only slightly more than that for a slipshod job. Get the most out of your present meters by careful maintenance and testing.

WHEN YOU BUY WAR-MODEL METERS . . . BUY THE BEST!

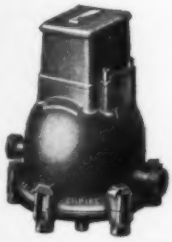
C The Pittsburgh-National Meters shown here all comply with the WPB limitation order. They provide top wartime measurement value. They will serve you faithfully both during the emergency and for years afterwards. Today, as always, there's a Pittsburgh-National Meter for every kind of service.

A new bulletin has been prepared describing all types of Pittsburgh-National war-model meters. Write, asking for Bulletin W-539.

EMPIRE VICTORY METERS

Sizes ⅝" and ⅝" x ¾"

An iron case domestic water meter employing the famous Empire balanced, oscillating piston principle of measurement. Has molded glass index box and breakable frost bottom. Interior parts interchangeable with the Empire Streamline Meter making conversion to bronze cases possible after the war if desired.



EMPIRE TYPE 9 METERS

Sizes ¾" and 1"

The 59th successful year for this oscillating piston meter design. Provides unexcelled accuracy with proven durability and low maintenance costs. Made with shallow base in both frost protected and non-frost models. Rectangular, straight reading register is standard, round reading optional.

EMPIRE LARGE CAPACITY METERS

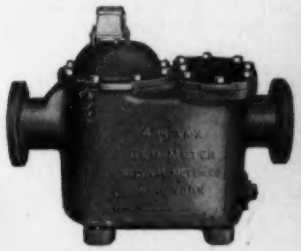
Sizes 1½" through 6"

The only balanced, oscillating piston meter made in sizes up to and including 6 inch. Provides the same accuracy, sensitivity and durability in large volume meters that is characteristic of the domestic sizes. Will handle variable flow rates, often to better advantage than compound meters.

IRONSIDE WATER METERS

Sizes ⅝" through 2"

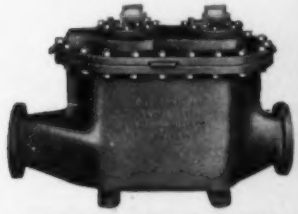
The Ironside is the cast iron war-model counterpart of the well known Arctic Meter. The working mechanism is directly interchangeable making conversion to bronze cases possible after the emergency is over. This meter is of the popular disc type with proven operating parts unchanged.



GEM WATER METERS

Sizes 2" through 12"

A velocity or propeller type meter for measuring the swift and free delivery of large volumes of water. All working parts are protected from dirt and abrasion by a large, built-in strainer. The design cushions the interior mechanism from the shock of water hammer.



EMPIRE COMPOUND METERS

Sizes 3" through 12"

Designed for services having a wide variation in delivery rates, this unit is a combination of the Empire oscillating piston meter and the Gem velocity meter. A built-in automatic valve diverts the flow at the proper change-over time. Provides exceptionally accurate measurement of large and small flows alike.

PITTSBURGH EQUITABLE METER COMPANY

NEW YORK · BROOKLYN · DES MOINES · MEMPHIS · OAKLAND · TULSA · CHICAGO · BOSTON

MERCO NORDSTROM VALVE COMPANY
Main Offices, Pittsburgh, Pa.

KANSAS CITY · PITTSBURGH · SAN FRANCISCO · LOS ANGELES · SEATTLE · HOUSTON · COLUMBIA · BUFFALO

NATIONAL METER DIVISION, Brooklyn, N. Y.

Water Meters

The Mill Cannot Grind With Water That's Past . . . . .

AN OLD PROVERB

. . . Neither can water properties operate efficiently or profitably on a flat-rate system or where meters are allowed to become inoperative or inefficient through lack of proper maintenance.

FOR TIPS ON WARTIME METERING SEE OTHER SIDE

Water Meters

PITTSBURGH EQUITABLE METER CO., . . . PITTSBURGH, PA.

ECONOMICS OF CLEANING AIR-DIFFUSION MEDIA

By JOHN J. WIRTS
Superintendent
EASTERLY SEWAGE TREATMENT WORKS
CLEVELAND, OHIO

THE PROBLEM of maintaining the porosity of air-diffusion plates and tubes used principally in conjunction with the activated sludge process and grease flotation and flocculation has been of growing concern to plant managers. The magnitude of the problem is increasing rapidly, due to two principal factors: (1) the widespread application of the activated sludge process during recent years; and (2) the increase of contributed industrial wastes incident to the war effort. Clogging is inherent with all diffusers required for efficient aeration of sewage. It follows, therefore, that such clogging must be accepted and that practical procedures must be developed to maintain efficient services. It is the purpose of this paper to discuss the need for and the process of cleaning diffusion media and to suggest a new scrubbing principle that has certain interesting possibilities.

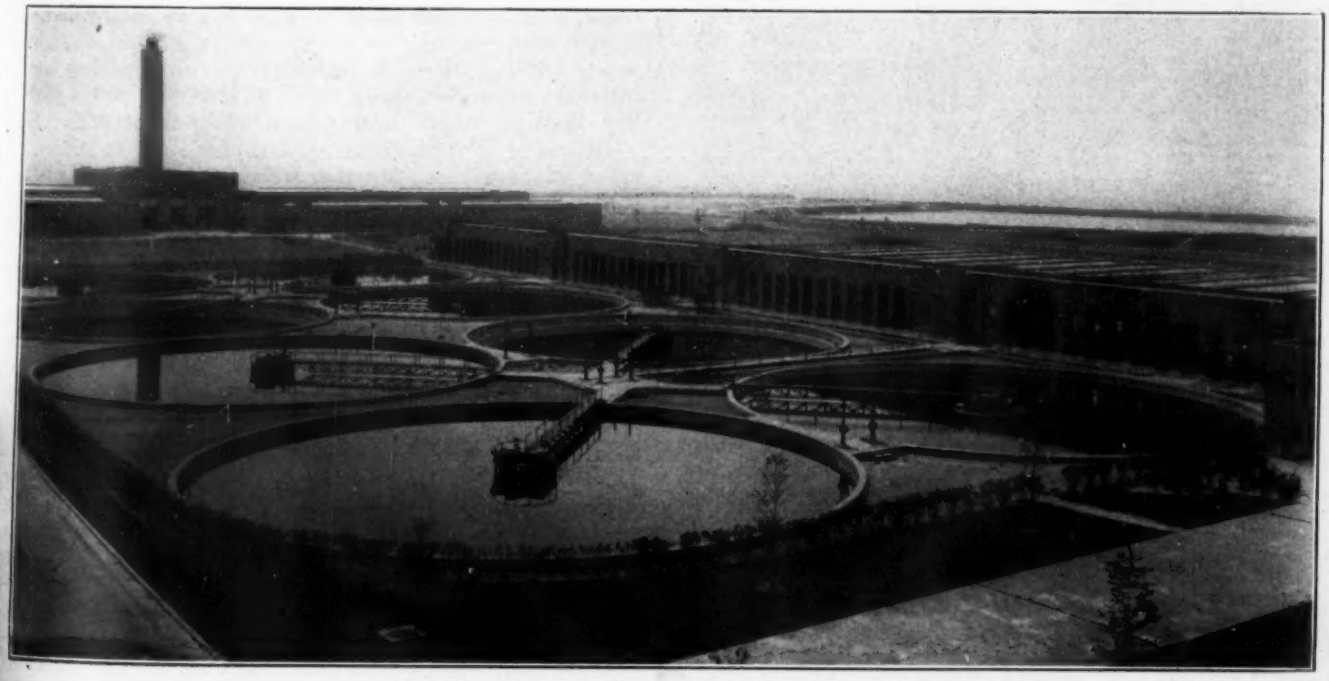
The Author

Perhaps the best method of demonstrating the need for clean diffusion apparatus is by a dollars and cents comparison of air costs at increasing blower discharge pressures. It is the back pressure, created by the loss of head across the diffusers, that is solely responsible for higher costs of compressed air. In Table I the theoretical yearly cost of compressed air is computed for the Easterly Plant of Cleveland. The comparison is based on the use of 1.0 cubic foot of air per gallon of sewage, 6.7 mills per kilowatt hour for power, and a yearly sewage flow of 33,000 million gallons. On this basis an increase of one pound in blower discharge pressure can be evaluated to approximately $20,000. The cost of air per million gallons increased during the four year period from $2.68 to $3.56.

Table II shows the gradual rise, month by month, of the blower discharge pressure. The present rate of plate cleaning at this plant seems to be just enough to equalize the rate of clogging, roughly estimated at 0.4 pound per square inch increase in blower discharge pressure per year. Better still would be a gradual decrease in pressure from the built up average of 8.0 pounds per square inch for 1941 and 1942. For sewage treatment plants in general it can be shown to be economically sound as a rule to begin a program of diffuser cleaning when the loss of head has increased 0.5 pound per square inch. This figure should be expected to vary from plant to plant, depending upon the cost of power at any particular plant. Cleaning cost should be more than offset by the decrease in power cost, otherwise there would be little advantage gained.

Easterly Studies

Since 1939 studies on diffuser plate cleaning have been carried on at the Easterly Treatment Works. Although this work began before there was any apparent need for cleaning, it was known that the character of sewage (high in iron salts and grease) was such that in due time the effects of clogging would become critical. Events subsequently have proved this assumption to be correct. Notable increases in blower discharge pressures were observed during the year 1940. Fortunately the plant was designed with the Burger removable cast aluminum plate manifolds, which made the clogged diffuser plates readily accessible for experimental purposes.



The Easterly Treatment Works, Cleveland, Ohio

TABLE I—RELATION OF BLOWER DISCHARGE PRESSURE TO COST OF AIR

Year	Discharge Press. Lbs. per Sq. In.	K.W.H. Required per M. Cu. Ft. Air	K.W.H. Cost per M.G.	Yearly Cost[1]
1939	6.8	400	$2.68	$ 88,440
1940	7.1	463	3.10	102,300
1941	8.0	540	3.62	119,460
1942	8.0	531	3.56	117,480

TABLE II—BLOWER DISCHARGE PRESSURE
(Pounds per Square Inch)

	1939	1940	1941	1942
January	6.8	6.9	7.3	7.9
February	6.5	6.8	**	8.1
March	6.5	6.8	8.1	8.0
April	6.8	7.2	8.1	8.1
May	6.8	7.3	7.7	7.8
June	6.8	7.4	8.1	8.0
July	6.9	6.9	7.9	7.9
August	6.9	6.9	7.9	7.9
September	6.8	7.1	7.9	7.9
October	6.8	7.2	8.0	7.9
November	6.8	7.3	7.8	8.1
December	6.8	7.4	7.9	8.0
Average	6.8	7.1	8.0	8.0

**Plant out of operation part of month, omitted from average calculation.

In the course of these studies, extensively reported in the *Sewage Works Journal*,[1] hundreds of plates were treated with various solutions, such as caustic soda, gasoline, muriatic acid, nitric acid and chromic acid. Previous investigators[2,3] have been limited principally to the use of a loss of head measurement on fixed diffusers; these investigators being unable to accurately report the percentage recovery in porosity by treating procedures.

[1]Based on 1.0 cu. ft. of air per gallon of sewage, 6.7 mills per K.W.H. and yearly sewage flow of 33,000 M.G.
Note: Actual 1942 cost of power for blowers was $92,393 due to a rate reduction of 1.3 mills per K.W.H. by change in power source from a private power company to the Municipal Power Division.

Fig. 1. Rubber Lined Acid-Soak and Rinse Tank for Diffuser Plate Cleaning
(The attendant wears rubber gloves and apron.)

The standard of comparison or rating of diffuser plates is permeability, which is defined as the number of cubic feet of air at 70° F. and 10 to 25 per cent relative humidity, that will pass through 1 square foot of diffuser area to the atmosphere, under a differential pressure through the diffuser equivalent to 2 inches of water when it is tested dry in a room maintained at a temperature of 70° and a relative humidity between 30 and 50 per cent. A precise determination of this value requires elaborate control of conditions and equipment. However, a more simplified procedure has been developed which has proved satisfactory for comparative purposes in testing plates.

An apparatus for permeability measurement was constructed after the type described by Beck.[2] It consists merely of a metal box for tightly holding the plate to be tested, an orifice meter for measurement of the rate of flow of air through the plate, and a draft manometer for measurement of pressure under the plate—i.e., the differential. The average test permeability of thirteen new diffusers was within one per cent of the permeability rated by the manufacturer. The maximum difference between test permeability and rated permeability for one plate was less than four per cent. In no case were air temperature and barometric pressure corrections applied. Relative humidity varied from 40 to 80 per cent with very little effect on the observed permeability. Damp or rainy days were avoided, as suggested by W. E. Holand.[3]

The functioning of the permeability apparatus should be checked by first testing with one or more reference plates of known permeability. Should the ratings not be normal, the apparatus should be checked for leaks. If there are no leaks the tests should be delayed until weather conditions are satisfactory.

Cleaning Equipment and Procedure

Twenty gallon crocks were provided for treating the diffusers, and a cylindrical rubber-lined steel soaking tank, as shown in Figure 1. The soaking tank was provided with water connections and a drain. Supports made of ⅜-inch rod covered with rubber tubing were hung in several of the crocks to hold the plates while the cleaning agent drained out after the treating period and prior to washing. The rubber-lined tank served as a storage tank for the drained, acid-soaked plates before the plates were transferred to the internal scrubbing machine (Figure 2), to be described later.

The method of cleaning consisted of three steps: (1) soaking the plates for several hours in a cleaning agent, consisting of a 2 per cent solution of sodium dichromate in sulphuric acid, (2) allowing the cleaning agent to drain out of the plate, and finally (3) subjecting the plates to a thorough scrubbing with compressed air and water mixture.

Prior to development of the scrubbing machine it was necessary to rinse the plates in as many as six baths of water, in order to remove the bulk of the cleaning solution. Even with this practice some of the agents remained inside the pores of the diffusers, with the result that on batches of 1,200 plates the average percentage of recovery of porosity was between 70 and 75, as determined by the permeability apparatus. Experience with these plates indicated that the reduction of head loss was satisfactory, but upon a second cleaning,

following a year of service in the aeration tanks, the residue remaining from the original cleaning was very difficult to remove. Since the clogging of the diffusers is not limited to the top surface, but penetrates into the interstices, it is essential that the interior of the diffuser be freed of all deposits, if the life of the diffuser is to be prolonged. The combination of compressed air and water was selected as the most readily available agents to remove the deposits.

The Internal Scrubbing Device

The machine sketched in Figures 2 and 3 and pictured in Figures 4 and 5 provides holders for four 12 in. by 12 in. by 1 in. standard diffuser plates, which are firmly held down by the foot control clamping device. Two 2-inch quick opening valves allow water, air, or both, to enter the manifold beneath the plates. The water is taken from a line under 70 pounds per square inch pressure and the air is from an air main operating at 8 pounds per square inch pressure. The duration of the scrubbing period is about one minute. During that time the valves are in an open position, forcing the mixture of water and air up through the diffusers in a violent manner. The wash water spills into the effluent trough and then to waste. A sheet metal hood shown in Figure 4 is hinged to the rear of the machine and folds down, enclosing the diffusers. The purpose of the hood is to protect the operator from acid spray.

Rubber gloves, rubber aprons and boots are provided the attendants for additional protection against chromic acid poisoning and strong caustic burns.

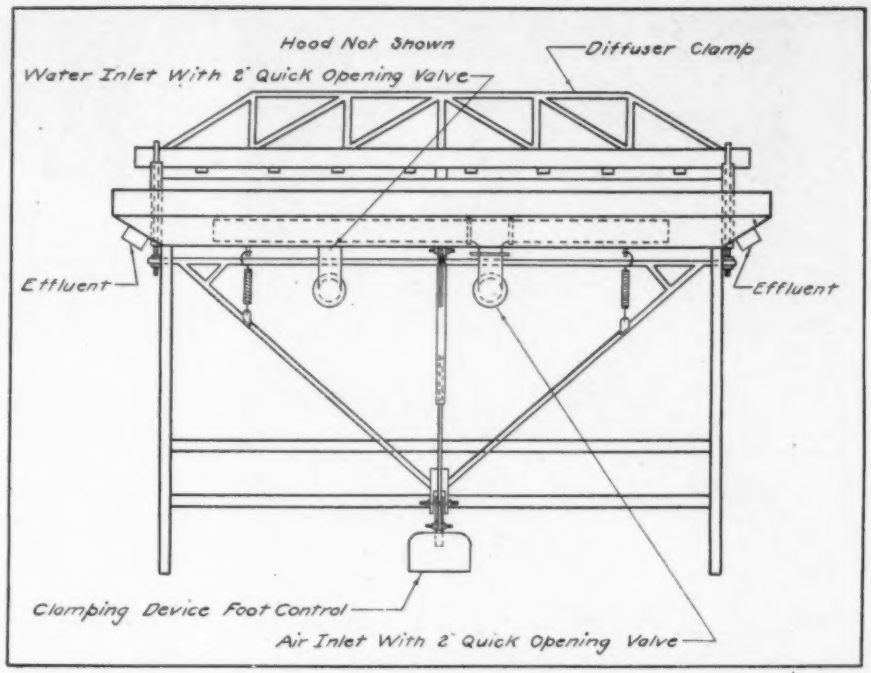


Fig. 2. Front View of Air-Water Wash Scrubbing Machine—Four Plate Capacity

The operator easily judges the time necessary for proper scrubbing by the uniform appearance of air bubbles (Figure 5). At the proper moment the quick opening valves are closed and the clamp released. The completely cleaned plates are then ready for service in the aeration tanks.

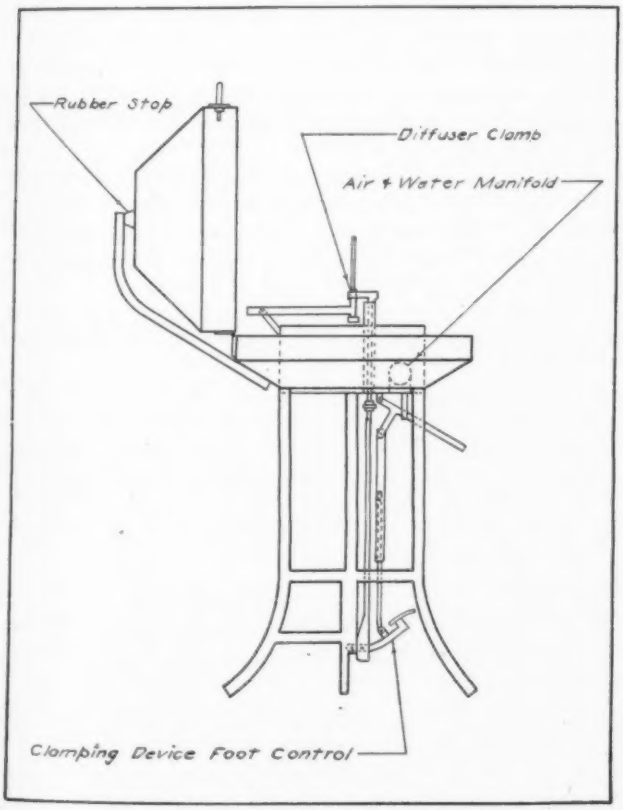


Fig. 3. End View of the Cleveland Plate Scrubbing Machine

Increase in Permeability by Scrubbing

During the year 1942, 4,800 diffusers were treated with a 2 per cent solution of sodium dichromate in sulphuric acid. After machine scrubbing, these were found to be within 90 per cent of their original porosity. Table III gives the typical results of cleaning an aeration tank containing 1,200 diffusers. Five batches of six plates were selected as representative. Their permeabilities when new varied from 39 to 43. The overall recovery after cleaning averaged 91 per cent. Similar results were obtained for tested plates from other aeration tanks.

TABLE III

TESTED PLATES FROM AERATION TANK No. 15 AFTER CLEANING

No. of Plates Tested	Rated Perm. (New)	Permeability After Treatment	Per Cent Recovery
6	39	36	92
6	40	36	90
6	41	37	90
6	42	38	90
6	43	40	93
Ave..6	41	37.4	91

A deposit of fine silt is found in the effluent trough of the machine after several hours of service. Quantitative analysis of this deposit showed a silica content of 70 per cent on a dry basis, the remaining 30 per cent consisting of a combination of aluminum and iron oxides. Although this deposit is in quantity very small per plate, its presence is difficult to explain. The silica content was identified as rounded grains of sand and the aluminum oxide consisted of very small particles of the diffuser plate. The iron oxide was that portion of insoluble iron that remained after the acid bath. It is believed that the activated sludge carries the silt re-

Fig. 4. The Plate Scrubber Being Loaded.
(Ease in operation is provided by arrangement of clamping device in open position and quick opening water and air valve.)

Fig. 5. The Plate Scrubber in Operation at Partial Rate with Spatter Hood Raised
Note the clamping bar locked in place by the quick-trip foot pedal. Operator is holding air-water mix valve partially open. Uniformity of bubbling constitutes the check-up on porosity recovery. This observation follows the high pressure air-water wash.

ferred to previously, and under certain conditions this silt is deposited in the pores of the plates, together with accompanying solids.

The unit cost of cleaning diffusers for the year 1942 was estimated at 45 cents per plate. Approximately 36 cents of this amount is charged against the labor in handling, that is, the labor of removing the plates from an aeration tank, chemically treating, machine scrubbing and replacing in the aeration tank. Sulphuric acid, dichromate of soda, caustic soda (when necessary), and miscellaneous items were estimated at 9 cents per plate.

Discussion and Conclusion

The permeability apparatus as described is a very useful and necessary device in developing cleaning procedures. The necessary tests for measuring the results can quickly be run on the permeability apparatus without elaborate corrections for humidity and temperature.

In routine plate cleaning, the 2-per cent dichromate solution in sulphuric acid is recommended. In certain cases in which grease is the principal clogging material, a strong caustic solution can be used first, then followed by the dichromate solution.

The use of compressed air and water in connection with internal scrubbing practically restores the diffusers to their original porosity. This is particularly true on the second or third times that the diffusers are cleaned, because residual clogging material is removed each time after a service period and is not allowed to build up inside the diffuser plates. Merely washing out the plates by a stream of water or by immersion in water is not sufficient to remove all of the clogging material and to restore the diffuser plate porosity.

It is sound economy to clean diffusers when the blower discharge pressure increase equals one-half pound per square inch.

It has been demonstrated that aluminum oxide ("Aloxite") diffusers can be economically removed from the Burger type aluminum holders, cleaned and returned on a full plant-scale basis at an overall profit in power savings.

The cost of labor in handling the diffusers is roughly 80 per cent of the total cost of cleaning operations, which is 45 cents per unit of one plate.

The development of an apparatus utilizing the principle of pressure scrubbing, that could be used on fixed diffusers, with suitable solvents, would eliminate much of the labor cost which is principally for removal and return of the plates. Such an apparatus, if made portable, would prove of almost universal use in plants using diffused air.

References

(1) Willard F. Schade and John J. Wirts, Diffuser Plate Cleaning versus Compressed Air Cost—Sewage Works Journal 14, 81-96 (January 1942).

(2) A. J. Beck, Diffuser Plate Studies—Sewage Works Journal 8, 22-37 (January 1936).

(3) W. E. Howland, Discussion of paper "Diffuser Plate Studies"—Sewage Works Journal 8, 485-488 (May 1936).

CONTROL OF ACTIVATED SLUDGE BULKING BY CHLORINATION

By E. E. SMITH

General Superintendent
DEPARTMENT OF WATER & SEWAGE TREATMENT
LIMA, OHIO

IN THE October, 1935, issue of WATER WORKS AND SEWERAGE, an article on the above subject, describing the use of chlorine for plant control of activated sludge bulking, was published by the writer. Since that time and for the period of nine years, chlorine, and chlorine only, has been used with uniformly successful results at Lima, Ohio, and such or similar use of chlorine has spread to other plants. The method consists of chlorination of the returned (recirculated) sludge.

A review of operating procedure developed through increasing experience with this simple but effective process may be of interest. The original experiments, as described in 1935, indicated that application of chlorine of less than 3 p.p.m. was ineffective and that economies could be obtained by applications of 5 p.p.m. When expressed in terms of ratio of p.p.m. chlorine to each per cent of suspended solids in the recirculated sludge, the corresponding limits were 2.0 to 2.5.

Records

Beginning in 1934 and each year since, chlorination of the sludge has been practiced during the summer periods of sludge bulking. The process is not continuous but is begun whenever signs of onset of bulking appear. By years, the occasions and total weight of chlorine used are given below:

The Author*

of parts per million chlorine for each per cent suspended solids in the returned sludge. The average rates of application for best results seem to be somewhat uniform at 6.5 p.p.m., which gives a ratio of 8.5 p.p.m. for each per cent of solids in the returned sludge. Under the above conditions, as observed at Lima, relief from bulking was usually experienced within seven days from its onset and treatment with chlorine.

When to Start Chlorination Important Consideration

For several years the point at which it seemed advisable to begin chlorination of return sludge was when the one hour settling test on the aeration tank effluent revealed the sludge "blanket" to be greater than 20 per cent by volume. It may be noted that in recent years, since the Lima plant has been operated at the full rated capacity of 8 M.G.D., the return sludge suspended solids it has become necessary to carry lower solids in the system.

The current practice is to carry aeration suspended solids between 1,000 and 1,500 p.p.m. with return sludge suspended solids from 7,500 to 10,000. The necessity of not permitting activated sludge to remain longer than essential in the final settling tanks, to avoid deterioration of sludge and absorption of oxygen from the supernatant liquid, has caused a general increase in volume of return sludge. The above considerations in addition to the increased plant load explain the marked increase in the use of chlorine in 1941 and 1942. It may be stated, however, that the use of chlorine for correction of bulking in a plant fully loaded did actually prevent any bulking sludge going over the final weirs and, as the most convenient and economical remedy, reduced the power requirements for air compression to a reasonable figure.

Economic Considerations

The total cost of operation per M.G. of the Lima plant for 1941 was $9.83 and for 1942 $10.21. The corresponding costs of power (all purchased) plus chlorine (used only for correction of bulking) were $3.42 and $4.53. These figures seem not unreasonable considering that the plant has been operating daily in excess of its rated capacity for approximately one-fifth of every 24 hours.

CHLORINATION RECORDS—LIMA, OHIO

Year	Pounds Used	No. Sep. Occasions	Max. p.p.m.	Min. p.p.m.	p.p.m. for each % susp. solids in return sludge Max.	Min.	Average days required to stop bulking
1934	1105	3	5.5	5.5	3.9	3.9	5
1935	1053	9	5.4	3.5	6.0	1.8	4
1936	1526	7	8.2	5.0	7.3	4.6	7
1937	1702	4	6.6	3.0	1.6	0.5	9
1938	2273	3	11.7	6.4	10.6	7.3	7
1939	2968	9	7.3	4.6	9.1	6.6	5
1940	2255	5	6.2	3.6	10.3	7.3	6
1941	5168	8	7.5	3.1	12.3	3.9	13
1942	9277	12	10.4	3.1	14.9	5.2	7

It will be noted from the above tabulation that since 1936 applications were held between a minimum of 3.0 and maximum of 11.7 parts per million of chlorine to the return sludge flow. Except for the summer of 1937, this figure corresponds to 3.9 ratio minimum and 14.9 ratio maximum when expressed in terms have been lower in percentage than in previous years. This circumstance has apparently created faster action but also has required more chlorine. For instance, in the years from 1934 to 1940 it was customary to carry around 1,800 to 2,000 p.p.m. of suspended solids in the aeration tanks and 15,000 to 20,000 p.p.m. in return sludge. With the gradually decreasing aeration period suspended solids

The local scheme of actual control of sludge bulking by chlorination is briefly described and illustrated by accompanying photographs. For the particular flows of return sludge (2 to 3 M.G.D.) during bulking periods about 150 pounds of chlorine per day are required at approximately 6 to 9 p.p.m. This calls for about 6 pounds per hour, which is nearly the maxi-

* The author is Chairman of the Ohio Section of A.W.W.A.

General View of Simple Chlorinating Equipment for Sludge Bulking Control.
Gas flow "Rotameter" and eductor panel connected to chlorine cylinder by heavy wall rubber tubing.

mum amount which can be withdrawn from a 150 pound container. The container is placed on the usual platform scales and is heated by two electric bowl heaters located on the floor near the cylinder.

Equipment

Between the auxiliary tank valve of the chlorine cylinder and the lower end of the Schutte and Koerting "Rotameter," used for dosage control, is approximately six feet of heavy wall rubber tubing. The upper end of the "Rotameter" is connected to an ordinary glass laboratory vacuum pump which discharges the resulting mixture of water and chlorine gas through ordinary garden hose to a point on the return sludge line between the final tanks and return sludge pump. Sufficient time and submergence is afforded under Lima hydraulic conditions for complete absorption of chlorine. The rate of application (indicated by float of the "Rotameter" and loss of weight on scales) is corrected hourly by plant operators on usual sampling rounds. The whole equipment may be assembled at an expense not to exceed $175 and is good for at least one annual season of operation without repairs. Glass tubing for connections and rubber bands for tubing clamps, with slight use of lacquer for facilitating and sealing the assembly of tubing, will produce an equipment which is quite satisfactory for its limited purposes.

In Summary

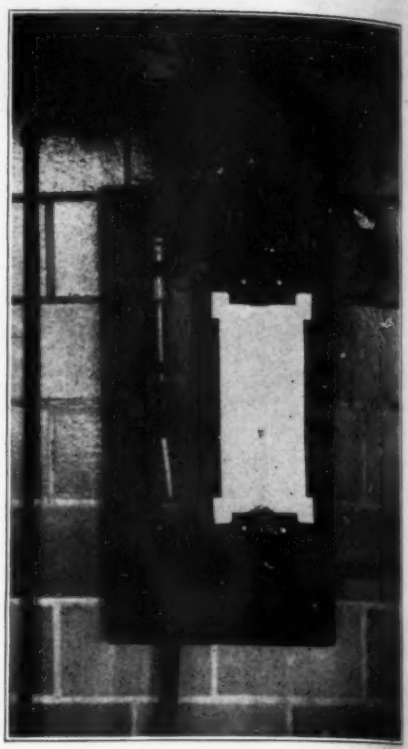
To summarize (always predicating any conclusions referring to sewage with the observation that the only consistent feature of sewage is its inconsistency):

1. Return sludge chlorination for correction of bulking has been practiced at Lima for nine years with success.

2. Chlorine should be used for *correction* of bulking only, not for prevention.

3. The amounts observed at Lima to be required for quick results are not less than 6 p.p.m. based on return sludge flow nor less than 8 p.p.m. for each per cent of solids in return sludge.

4. Nearly complete recovery from bulking may be expected at Lima within seven days after the beginning of chlorination of return sludge,



Close-up of Chlorine Control Panel
Water feed line on right connects to glass laboratory eductor into which is sucked the chlorine gas measured through the almost invisible "Rotameter" in front of the white cardboard. The little rotating top-shaped float can be seen about one-third way up the graduated and calibrated glass rate indicating.

and recovery has been effected on many occasions after as few as three days of chlorination when started at the optimum time.

5. With effective reliance upon chlorination as a corrective of bulking, power requirements for air compression may be reduced to the minimum, and the combination of the above considerations should result in marked economy operation.

Sewage Federation Heads Propose Plan for Training Sewage Operators for Military Posts

A. M. Rawn, Chief, Sewage Section, Governmental Division, W.P.B., and Vice Chairman of the Federation of Sewage Works Associations, and George J. Schroepfer, Supt., Minneapolis Sewage Treatment Works and President of the Sewage Federation, have proposed a plan for training operators of sewage treatment plants of military posts.

The idea is to have the operator or employee of the U. S. Army Engineers spend at least one month, possibly longer, at some nearby municipal sewage treatment plant. During that period the employee would work under the direction of the sewage plant superintendent and other technical personnel. Under such guidance the trainee would perform every operation incidental to the sewage treatment plant operating processes, including routine laboratory work.

At the end of the training period it is hoped that the "student" will have a familiarity with the problems of sewage plant operation which he probably could not obtain in six months in a short school. With such training he should be equipped to serve the needs of the military authorities far better than otherwise. If the nearest municipal plant is not of the same type as that at the military post, then the "student" should be sent to the nearest plant of such type.

Not only will this plan benefit the military service but it will also tend to reduce the movement of municipal sewage plant operators into military camps, which is crippling the efficient operation of municipal sewage works.

The California Sewage Works Association has already made a move to institute such training and the idea has also been suggested to the Repair and Utilities Branch of the U. S. Army Engineers—so far without any observable action having been taken.

MONTANA SECTION'S WARTIME CONFERENCE

A Report of the Section's 18th Annual Meeting

By H. B. FOOTE*
Chief Engineer
MONTANA STATE DEPT. OF HEALTH

WITH an attendance of 71 and a reported increase in membership of over 10 per cent the Montana Section AWWA held a successful Wartime Conference in Billings, Mont., May 14 and 15.

Chairman F. F. Palmer opened the meeting and introduced Mayor Biddinger, of Billings, who welcomed the registrants and told of his vital interest in the local water supply and his belief in the need for attention to sewage treatment in the future.

New Chairman and Vice-Chairman
Chairman, S. R. Young, Supt. of Water Forsyth, Mont.

Vice-Chmn. A. E. Heath, Foreman, Water Dept., Billings, Mont.

Mr. Palmer, as retiring chairman, addressed the session stating that the Mutual Aid System had been put into operation in Montana with the sole idea of being prepared for any emergency, whether it be from enemy action or other causes. He also stressed the necessity of the water works operator working all the time in order to maintain his own water supply system at its highest peak of efficiency regardless of the difficulties, or shortage of critical materials for operation or maintenance. Mr. Palmer also stated that, while efforts to secure legislation, giving the water works operator protection and security in his position, failed in the last legislature he believed that in the future further effort should be made at least to require licensing.

AWWA's President-Elect Talks

The chairman then presented Mr. Samuel Morris, president-elect of AWWA, who outlined the present situation as it applies to new developments in engineering. New steels, plastics, fuels, glass, rubber, and power developments will, after the war, probably affect the water works operator and manager. Higher efficiencies and lowered costs of operation should be in order. Mr. Morris stressed the necessity of keeping in touch with all these new developments in order that we will be abreast of the times when we are back to normal operating conditions. The tremendous growth in ability of our American people to produce will necessitate a high national income if we are to avoid a depression and if we are to find a market for these improved materials. Those new developments which have come because of the need for war purposes will find their place in the scheme of things, and the water works man will benefit as will all of the people of this country, said Dean Morris.

Fuller Award to Carroll

At the business session held at the close of the meeting the following officers were elected: Chairman, S. R. Young, Hardin; Vice-Chairman, A. E. Heath, Billings; Secy.-Treas., H. B. Foote, Helena; Trustees, John Hall, Fort Shaw, and C. C. Moore, Great Falls. Bozeman was selected as the 1944 meeting place and a committee reported the desire for an annual school for operators to be held again in conjunction with the annual meeting, just as soon as conditions will allow.

Kenneth C. Lauster, State Sanitary Engr. Bismarck, N. Dakota
(Secy. N. Dakota Water and Sewage Assn.)

Dean Sam Morris, Leland Stanford Univ. Palo Alto, Calif.
(Pres.-elect of A.W.W.A.)

H. B. Foote, Director, Water and Sewage Div., State Dept. Health, Helena, Mont.
(Secy.-Treas. of the Section and Immediate Past Chm'n.

Hosts
A. L. Hewett, Supt. of Water and Mayor H. E. Biddinger Billings, Mont.

The Fuller Award Committee nominated Mr. Eugene Carroll of Butte, Mont., as the recipient "in recognition of his engineering skill and achievements, his long and unselfish service to the water works profession, and his contributions to the development and progress of the Montana section of the American Water Works Association". Mr. Carroll has been a member of the AWWA since 1904, is a charter member of the Montana section, has lent his influence and support to all its activities, and is well known in the water works field.

Mutual Aid

The Mutual Aid program, as operated in Montana, was briefly outlined by H. B. Foote, State Water Coordinator. Ninety-two per cent of the urban population in Montana is voluntarily under the system and would benefit directly by it in case of emergency. No emergency has arisen to determine the effectiveness of the system, but the organization is intact and ready to function at any time. The

*Secy.-Treas. Montana Section of A. W. W. A.

other 8 per cent should be under the system and doubtless will be as soon as personal contacts can be made.

Substitute Materials

Mr. C. C. Moore of Gt. Falls described some of the substitute materials which are available and which are not critical. Fiber pipe, plastic pipe and fittings, and lead alloys were described. These do not fulfill all of the requirements in the field of water supply, but they will go a long way toward meeting the present needs in the replacement of steel and copper wire, still highly critical. The prospective user must study the characteristics of the substitute material before using it, for these materials have definite limitations in many cases.

Sewage Plant Financing

Mr. C. J. Williams, representative in the State Legislature from Yellowstone County, told of the legislative measure for the financing of sewage treatment plants. The plan, as finally enacted, is that revenue bonds may be issued either as serial bonds or amortization bonds backed by sewer rentals. This is similar to the method in operation in other states for a number of years.

War Gases; Post-War Planning

Major G. E. Arnold of the Public Health Service gave an interesting talk on war gases as they might affect the public water supply. He said that there are probably three of these to be most concerned about. Phosgene, mustard, and chloropicrin are of the most concern, since these are probably those which would be used by the enemy. However, the usual water filtration plant will remove all danger from these gases, and if such is not available, activated carbon is useful and high doses of chlorine also are effective.

Mr. Roy Covert told the gathering that in any post-war planning, it is highly essential that any appeal to the emotions must be accompanied by a clear, concise planning with specifications and blueprints. We in the water works field must keep clear heads, plan definitely for the future, and be ready to assume our responsibilities whenever peace comes.

Corrosive Water Control

Mr. Ken Lauster, State Sanitary Engineer from North Dakota, related experiences at Richardton, N. D., where the well water in the city is highly corrosive to metal pipe. This is a problem of long standing and various remedies have been attempted since this was first reported to the Montana Section in Miles City in 1940. The most effective treatment, where the water contains high carbonic acid and a high chlorine demand appears to be the application of metaphosphate and chlorine in

C. C. Moore, Dist. Manager, Crane Co. Great Falls, Mont. (New Trustee of the Section)

M. F. Dixon, Chief Operator, Filter Plant Billings, Mont.

President Wm. Cobleigh, State A. & M. College, Bozeman, Mont. (One of the earliest "wheel-horses" in the Section)

large amounts. These in combination appeared to reduce the corrosion, prevent growth of bacteria in the pipe lines, and eliminate hydrogen sulphide development in the system. The experiences at

Major G. E. Arnold, U.S.P.H.S.—O.C.D. San Francisco, Calif. and The Retiring Chairman—F. F. Palmer Supt. of Water and City Engineer Forsyth, Mont.

Richardton indicated that the double treatment reduced the troubles with red water to a minimum.

Chlorine Kills Tularemia Bacteria

Dr. Steinhause of the Rocky Mountain Laboratory at Hamilton, Montana, after a study of the effects of liquid chlorine on Pasteurella tularensis, concluded that chlorine will kill the organism which is the cause of *tularemia* although possibly the doses may be slightly greater than required for other purposes in water treatment. The public will be protected from this disease so far as drinking water is concerned if chlorine disinfection is practiced. These conclusions were reached following a study conducted jointly by the staff of the Rocky Mountain Laboratory and H. B. Foote, of the Montana State Board of Health. The studies covered a period of three years. There is a widespread occurrence of the causative organism in Montana streams. Epidemics of tularemia caused by drinking water in other countries have occurred, and all who have studied this situation are fearful that our people may contract the disease from drinking water. While few if any cases have so far been traced to this source in Montana or any other mountainous areas, the definite possibilities are present so far as any workers in the field can determine. Military authorities provide their troops with chlorine tablets, and the work which has been done in the investigation of the effect of chlorine on P. tularensis indicates so far that chlorine is the best agent available for this purpose. Dr. Steinhause believes that a definite advance and a definite contribution to information has been made from this investigational work. It is fortunate that coincident with the finding of the organism so widespread, some assurance is given at least that chlorine disinfection is effective.

Billings Water System

Mr. A. E. Heath of the Billings City Water Department gave an account of the city water system, describing its growth from the earliest days to the present, in which the filtration plant was constructed. The present plant has a total capacity of ten million gallons per day, is well equipped mechanically, and also with laboratory facilities to produce the highest quality of purified water, contrasting that with the muddy, contaminated water of the Yellowstone River from which the supply is taken.

The meeting closed with a banquet and dance with 150 in attendance.

Casad Voted Fuller Award

Chas. C. Casad, City Engr. and Supt. of Water for Bremerton, Wash., has been voted the Fuller Award by the Pacific N. W. Sectiton of A.W.W.A. He was cited for "spectacular achievements in providing pure water for a population that tripled in the past year."

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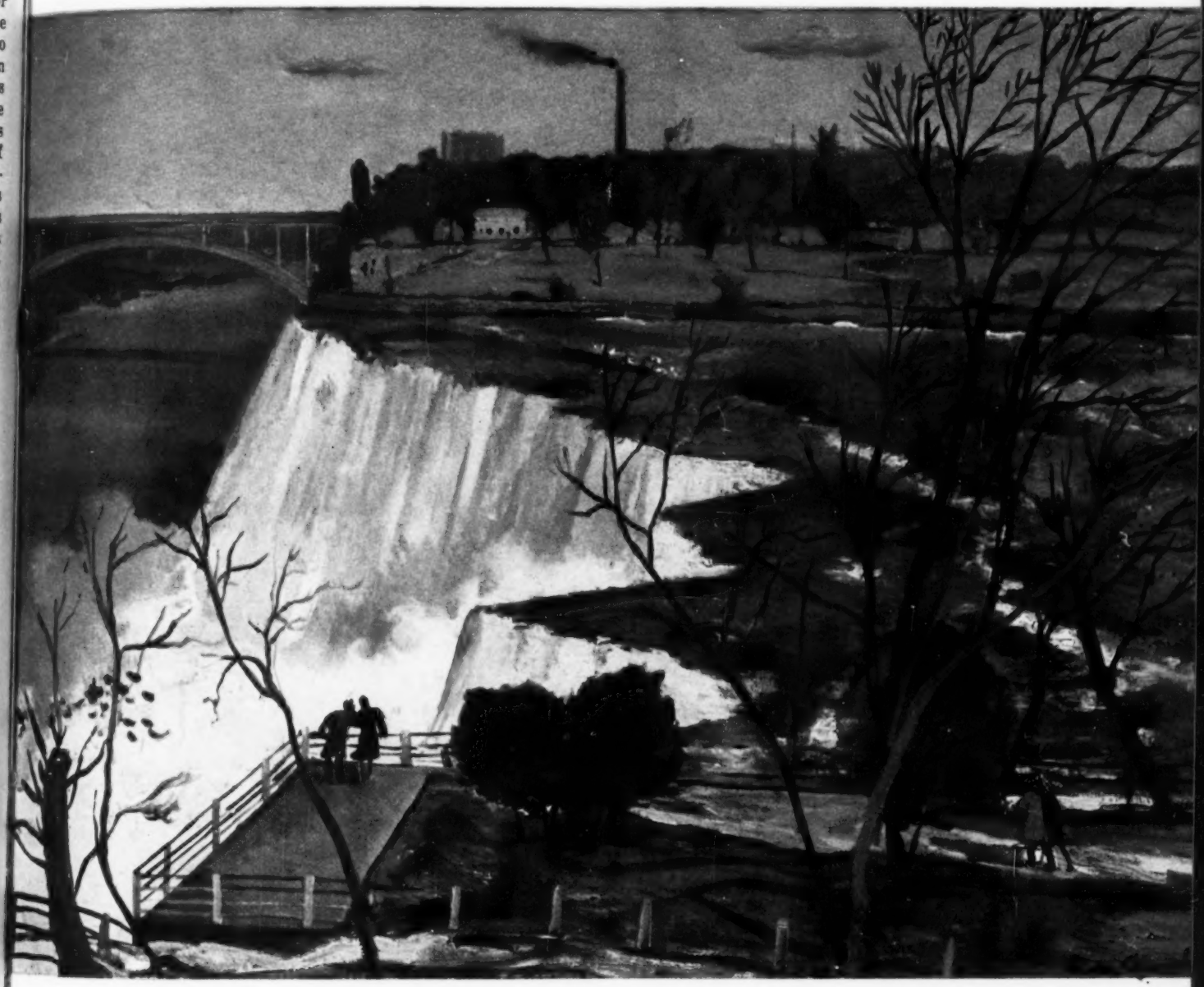

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MD.-DEL. WATER AND SEWERAGE ASS'N CONFERENCE

At 17th Annual Meeting Sets Precedent, Elects Feminine Secretary

By GEORGE E. SYMONS
Associate Editor

Presidents

(Incoming)
R. J. Stewart
Edgewood, Md.

(Outgoing)
R. A. Norris
Sykesville, Md.

REWARDING the faithful services of Miss E. Virginia Gipe, who has acted as recording secretary for all of the 17 annual meetings without exception, the Maryland-Delaware Water and Sewerage Association voted her a life membership and then proceeded to elect her secretary and treasurer as well as recording secretary. In further tribute, it was voted to raise the annual salary for the recording secretary and pay both salaries for Miss Gipe's future service. Thus, as far as we are aware, Miss Gipe becomes the first woman honored with a life membership in any water or sewage association and the first woman to hold the important office of secretary and treasurer. Indeed, quite a tribute. For more years than she has served the Association Miss Gipe has held the position of secretary to the Chief Engineer of the Maryland State Department of Health.

Other officers and trustees elected were: President, R. J. Stewart, Edgewood, Md.; 1st Vice President, E. C. Cromwell, Colgate, Md.; 2nd Vice President, John W. Alden, Wilmington, Del.; Secy.-Treas., Miss E. V. Gipe, Baltimore, Md.; Trustee (4 year term), Ralph E. Fuhrman, Blue Plains, D. C.; Trustee (1 year term), Joseph Benton, Newcastle, Del. The hold-over Trustees are R. C. Willson (Hagerstown) and James W. Engle (Washington).

Morning Technical Session

Under the chairmanship of Robert A. Norris, retiring president, the first session was opened with an address of welcome by the Hon. Howard W. Jackson, Mayor of the City of Baltimore. The mayor's greeting was flavored with patriotism and interspersed with reference to the important work of water and sewage men in these times, as well as normally.

Five speakers talked about **Substitutes and Alternatives Used in Wartime Construction and Operation.**

Gustav J. Requardt, of Whitman, Requardt and Smith, Engineers, Baltimore, as first speaker, commented on the change in attitude toward standards of construction and inspection. In 1940 everything was constructed to last for a long time and all the trimmings, including brass revolving doors, were being specified. In 1943, the idea has been to build quickly, with the life expectancy of the construction but a few years. As an example, Mr. Requardt told of one water reservoir floored with only 1½ inches of concrete. Drawings are made with pencil on vellum, thus eliminating the time-consuming process of inking tracings and also making possible frequent changes in the drawings as Army requirements change.

Trustee
Ralph E. Furhman
Washington, D. C.

Retiring Secy.
John H. Schillp
Baltimore, Md.

Buildings have been built more rapidly than ever before, plans for roads and railroads have often been drawn after the road has been built; the original layout and elevations being mere sketches. Development of operating personnel coordination in the engineer's office has made possible this speed of preparation of plans and supervision of construction.

New Secy.-Treas.
E. Virginia Gipe
Baltimore, Md.

New Vice Pres.
John W. Alden
Wilmington, Del.

W. Clarke Gardner, City Engineer, Salisbury, Md., said that substitution and alternatives required ingenuity on the part of every one concerned, but that substitution might prove more economical in the long run, both for construction and operation. Although Salisbury is a small place, it has received many suggestions for substitutes, one of which was the use of double strength terra cotta pipe for an airport sewer, instead of concrete. To resist landing shock of heavy planes, the pipe was encased in concrete.

Salisbury with its 4500 g.p.m. well supply, 45 miles of mains and 500,000 gal. storage tank might easily be rendered useless with bombs. An alternate water supply was needed and the lake was not considered a good source. Therefore, plans were made for other driven wells throughout the city and connected to the mains through automobile motor operated pumps.

Because of W.P.B. limitations, Baltimore has had to use Substitutes and Alternatives, said **Mr. George E. Finck,** Sewerage Engineer, Baltimore. Double strength terra cotta pipe, or non-reinforced monolithic concrete pipe and "Armco" wood pipe culvert have been used. Monolithic pipe requires more form lumber than other installations.

Although 100 iron manhole frames and covers still exist in Baltimore, these are being held for maintenance. It is planned to use

(1) (2) (3) (4) (5)

(1) *Ted H. Kain, Gen. Mgr. Columbia (Pa.) Water Co., Jo. D. Acker, R. D. Wood Co., Phila.*

(2) *"Al" Brumley, Vice Pres., Stuart-Brumley Corp., Balto., Burt Graham, Chemist, Stuart-Brumley Corp.*

(3) *Eugene Conton, Balto. Mgr., Badger Meter Co., "Ted" Wood, R. D. Wood Co., Phila. J. S. Strohmeyer, Div. Engr. Balto. Bureau of Water.*

(4) *Jack M. Divin Leadite Co., New York City. "Mike" Marinelli, Inter-County Const. Co., Hyattsville, Md.*

(5) *R. C. "Smoke" Clement, Div. Mgr. Wallace & Tiernan, Newark, N. J., A. P. Rudder, Dist. Mgr. W. & T., Washington, D. C.*

concrete frames and grates. (See May issue of WATER WORKS AND SEWERAGE for an article on substitute manhole frames and covers.)

In spite of available money, requests for pumping stations have been turned down. Maintenance is performed by overworking a small crew. Often, construction is planned to last only until something better can be put in after the war.

"Hall and Hall"
(Chief Engineers)

George Hall, Md. Dept. of Health, Baltimore

Harry Hall, Washington Suburban Sanitary District

(Both started with the Ind. State Dept. of Health as just "The Hall Brothers." Here they are each a "Chief")

William B. Spencer, of the Consolidated Engineering Co., Inc., Baltimore, presented the contractor's side of the Substitute and Alternatives topic. Because materials often become critical during the design period, it is impossible for the engineer to keep abreast of the market price, preference rating and other factors. It therefore benefits the contractor in the speeding of the job to make substitutions or alternatives a part of the specifications. The availability of certain items varies in different localities and this is another reason for specifying alternatives. One phase of engineering and contracting which has not changed is the need for organization and integrity, not only in the engineers employed but also in the contractors selected. Care in the choice of a good contractor will often eliminate many difficulties and troubles.

Carl A. Hechmer, Maintenance and Operating Engineer, Washington Suburban Sanitary Commission, Hyattsville, Md., complained that while there were delays and difficulties in obtaining Substitutes and Alternatives, the greatest concern was a lack of proper operating personnel. Not only has the number of men formerly available been reduced to about half, but many of the replacements today have but half the efficiency of former employees. Inspection of the distribution system and of sewers is not properly carried on, and yet sewer stoppages are more important now inasmuch as the great influx of population into the area has resulted in the using of basements for living space.

Regarding Civilian Defense measures, Mr. Hechmer said that apparently the utilities had been left to fend for themselves. In spite of the fact that auxiliary pumps and emergency chlorinators have been purchased in his district, it is impossible to obtain a priority to purchase the hose necessary to make these pumps function in case of emergency. On the other hand, the fire department has been able to obtain fire pumps and hose. "But what good is it to them if the water service emergency system cannot be put to use?"

Priorities Information

H. Lloyd Nelson, from the Water Division of the War Production Board, spoke unofficially on the subject of Order U-1 and Priorities Preference ratings, answering many questions as has been his custom at many previous meetings this season. According to Nelson, lead pipe and caulkings are easy now, as is cast iron pipe and fittings in the smaller sizes. Steel is still quite critical, as is copper. Aluminum is out of the question and restrictions are still in force on reinforced concrete and Transite pipe.

Programmers

G. L. O'Brien, Design Engr., Bureau of Water, Baltimore

Carl Hechmer, Maint. & Oper. Engr., Washington Sub. San. Dist.

(1) (2) (3)

(1) *W. A. Welch, Ind. Chem. Sales, Phila., Pa., John Hellman, Water Engr., Bethlehem Steel Corp., Baltimore, Md.*

(2) *Dick Wagner, Pres. Zeolite Chem. Co., Midford, N. J., W. H. Eastburn, Mathieson Alkali, Phila., E. W. Gray, Builders Providence Co., Phila. R. C. Wilson & Supt. Filtration, Hagerstown, Md.*

(3) *Leon Small, Bureau of Water, Baltimore, S. C. Blackburn, Ch. Engr. Div., Bur. Water Baltimore*

In reply to a question as to how Mr. Hechmer might be able to obtain hose for his emergency pumps, it was suggested that the request perhaps should not be on the basis of

Civilian Defense. In more serious vein, information of interest to various persons was given. The answers to several questions may be summarized as follows. U-1 supplements

Programmers

Roy H. Ritter
Whitman, Requardt & Smith
Baltimore, Md.

W. H. Wisely
Exec. Secy
Sew. Wk's. Fed.
Urbana, Ill.

W. Clarke Gardner
City Engineer
Salisbury, Md.

must be included in the withdrawals from inventory. Copper may be used only for actual repair to copper services now in use. If a house has already been built and contains plumbing, one should write to Arthur E. Gorman, Chief of the Water Division of W.P.B., stating the materials needed to connect a service to that house. In general, new services are not allowed without special permission.

Regardless of the dollar value of materials needed for work, one should not send the request, or a PD 1-A to a regional office. Write direct to the Water Supply Division, W.P.B. A new application form (UF) will replace the old PD-200 and PD-1A. New application blanks will contain several sets of questions, one set of which will apply to the particular case. Not only will Order U-1 be liberalized, but it appears that even now a number of things, that at first appeared impossible, can be done. In other words, the order is more liberal than was thought. For example, replacements can be made if needed for the war effort.

All dollar values and figures in Order U-1 are for materials only, and do not include labor. Eight to ten water utilities daily report that it is impossible to stay within the minimum inventory limits, and request permission to increase the maximum stock allowable on hand. Some idea of the actual inventory requirements of a utility were given from a test survey of seventy-four plants of one company. It was indicated that sixty per cent of the 1942 inventory plus a quarter-year supply was the minimum for proper operation. Fifty-four of these 74 plants had too few supplies in inventory under the U-1 requirements. It is expected that the allowances will be liberalized.

C.M.P. materials are products receiving no further fabrication after the original mill fabrication. Brass fittings, for example, are B products inasmuch as they have received further fabrication. The only controlled material that a water works superintendent need worry about is steel pipe as received from the mill and copper wire and copper tubing.

There is nothing that can be done to obtain relief from the so-called

One of the Sessions
(McComas Speaking)

Victory meters, because copper and bronze are too restricted. The only plants, so far, required to file the inventory form UF-13 are those serving a population of 50,000 or more. Information from such plants will produce inventory data on plants serving 65 per cent of the total population.

Regarding C.M.P. certification, it is important that one differentiate between M.R.O. (maintenance, repair and operation) under Order U-1 and PD-200 for construction. As for supplies for M.R.O. under U-1, it is only necessary to reproduce on the purchase order the authorization statement, as given in the U-1 Order of April 17, 1943. There is no C.M.P. problem for a utility for anything it can do under Order U-1. For construction problems using form PD-200, one should use form 4-C and obtain these forms from the suppliers. Then file a schedule of required delivery.

Programmers

James R. McComas
Sr. Asst. San. Engr.
Md. Dept. Health
Baltimore

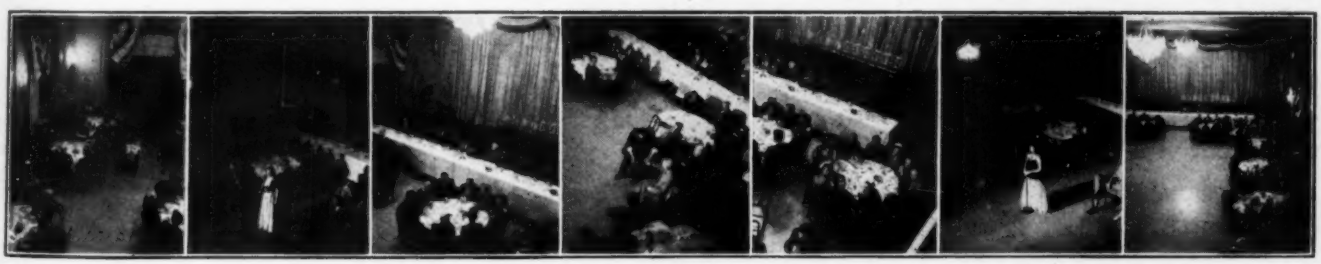
T. F. O'Connor
Off. Chief of Engrs.
War Dept.
Washington, D. C.

Capt. C. W. Klassen
Comm. on San. Engr.
W.M.C., Washington

Mr. Nelson concluded on a highly optimistic and satisfying note to the effect that any person may now obtain action from the Water Division within two days, as its work is now up to date and no longer three months behind.

Facts About the Sewage Federation

At the close of the Thursday morning session, W. H. Wisely, Executive Secretary of the Federation of Sewage Works Associations, spoke briefly on the aims of the Federation and the advantages of membership therein. Particular mention was made of the *Sewage Works Journal* and the efforts being made to remedy the deficiency of operating papers published. The Federation aims are to advance the knowledge of sewage treatment, to aid and assist member associations, to promote the welfare of members and render other services. Committees on research, war, sewage works practice, and operating reports, are some of the functioning parts of the Federation.



Shots of the Annual Dinner

Manuals on sewage works practice will be available to members when completed. Awards are made for the best papers published. A membership drive is now on and a $25 war bond will be given to that person obtaining the most new members.

Familiar Faces

Norman Kenny
Whitman Requardt & Smith
Baltimore, Md.

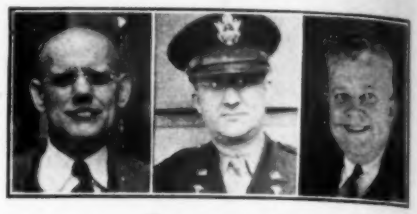
Al. L. Genter
Cons. Engr.
Baltimore, Md.

J. G. Patrick
Chem. W. Va. Pulp & Paper
Luke, Md.
(Past President)

Sanitation in Three Wars

Mr. James R. McComas, Senior Assistant Sanitary Engineer of the Maryland Dept. of Health, has made a hobby of collecting information on wartime sanitation. From his files came a story of sanitation, or the lack of it, in the wars from 1861 to 1918. With the advance in health measures the incidence of intestinal diseases had shrunk measurably by 1918, but in the wars before, typhoid, dysentery, and diarrhea rampaged. In the Civil and Spanish-American Wars the absence of sanitation in its relation to water and sewage was the direct cause of more casualties and deaths by far than battle wounds.

In 1861, a "sink" was an excavation, 3 ft. by 10 ft. by 5 ft. deep, into which all excreta was discharged. Devoid of architecture and any semblance of aesthetic features, it not only smelled to "high heaven" but by virtue of leaching rains it polluted any well or other water supplies in army camps. By 1918 the "sink" had become a latrine with a cover and other improvements. Lack of sanitary facilities was also typical of all army prisons. In one prison there was but one toilet for each 6500 men. Statistics on disease incidence and death in these military prisons are appalling. More men died in Point Lookout prison alone than were killed in Pickett's Division at Gettysburg. Sixty per cent of the cases and deaths were caused by diarrhea and dysentery. At Anderson, there was a 90 per cent incidence and 13,000 deaths. An interesting footnote was the accusation by some medical men that army beans were the cause of intestinal disease. In those days, too, men believed the drinking of muddy river waters was salubrious for the health. Mr. McComas presented slides to show the intestinal disease rates in the period of 1861-1918 and the effect of wars upon these rates. These curves (reproduced) dramatically reveal the improvement in health conditions during the period, as well as the great upsurges in disease when wars break out.



Programmers

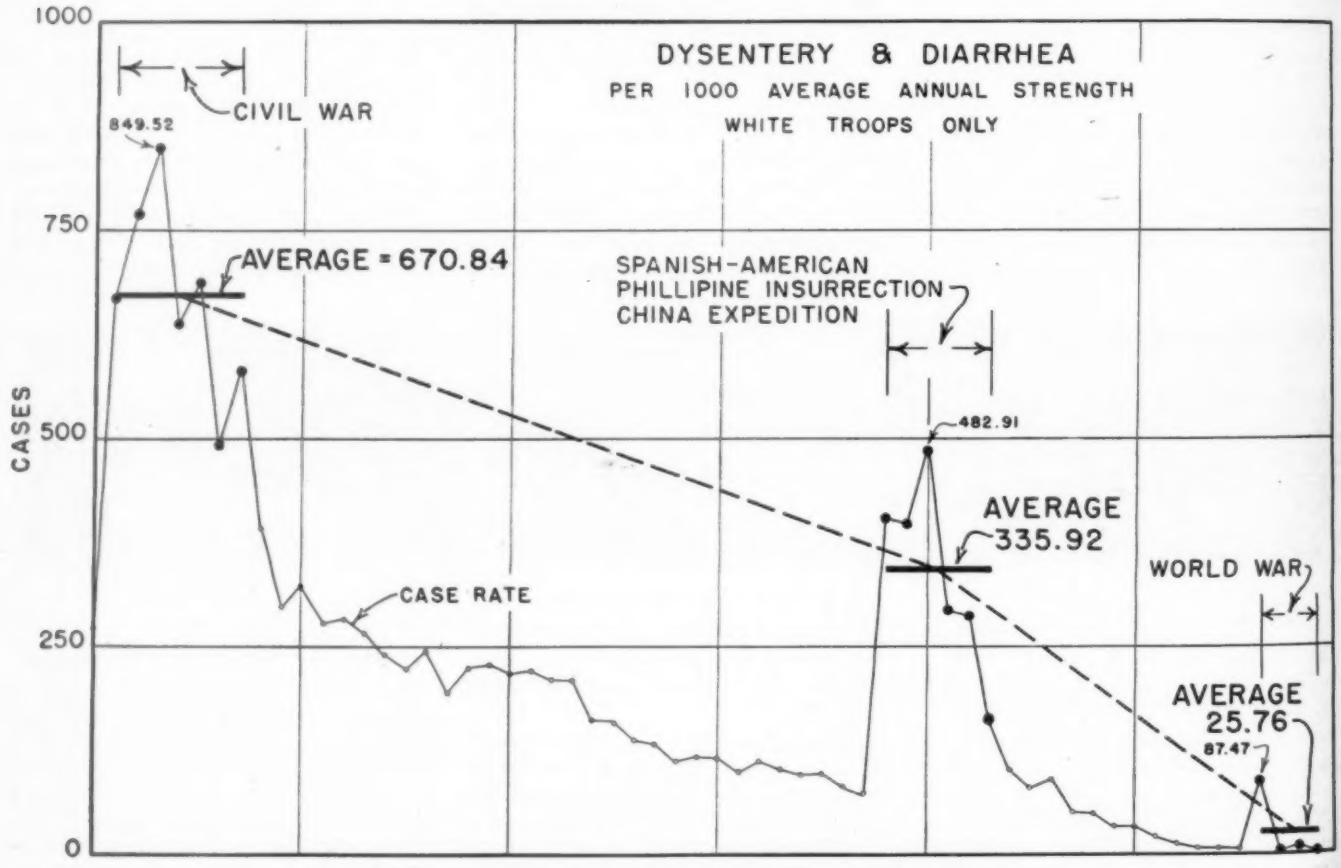
George E. Finck
Sewerage Engineer
Baltimore, Md.

H. Lloyd Nelson
W.P.B.
Washington, D. C.

Maj. J. J. Gilbert
Sanitary Corps
Washington, D. C.

War Sanitation—1943

Major J. J. Gilbert, Sanitary Corps, Surgeon General's Office, Washington, followed Mr. McComas and described the function of the Sanitary Corps and its works in preventing such disease catastrophes as occurred in previous wars. Functioning within the Medical Corps, the Sanitary Corps is concerned with water, sewerage, mosquito and rodent control and other public health



Records of Intestinal Diseases During Three Wars
(A Graph Developed by J. R. McComas, Md. State Dept. of Health)

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Manufacturers' Representatives

(1)"Ed" Eyler, Balto. Mgr. Pittsburgh-National Meter Co., (2) "Bob" Turner, Dist. Mgr. Rensselaer Valve Co., Phila., (3) B. D. Hubley, Phila. Mgr. Hersey Meter Co., (4) W. A. Darby, Dorr Co. N. Y. City, (5) "Jo." D. Acker, R. D. Wood Co., Phila. (6) Alan A. Wood, %Proportioneers%, Wash., (7) E. S. Shiddell, Dist. Mgr. Electro Rust-Proofing Co., Phila., (8) Sid E. Linderman, Exec. Vice Chm., C. I. Pressure Pipe Inst., Wash. D. C.

measures. Major Gilbert cited an instance in the Black Hawk War of 1832 when the officer in charge issued an order stating that certain men had been stricken with cholera because of becoming intoxicated. Punishment for drunkenness was for a man to dig his own grave. Attitudes have changed considerably and the Medical Corps, through the Sanitary Corps and in cooperation with the Army Engineers, now see that soldiers both in camps and in the field are provided with proper water and sewerage facilities, properly operated.

Major Gilbert showed some of the typical sewerage installations in various camps, and also means of disposing of garbage and grease. It was stated that there had been no increase in the incidence of typhoid and similar intestinal diseases since 1911, partly because of immunization, and partly because of good sanitation. In World War I dysentery and diarrhea incidence was 18.45 cases per 1000 men per year. (Compare to the approximately 670 cases per 1000 men per year in 1861-67.) In World War II the incidence is only 10.19 cases per 1000 men per year. This is but slightly greater than the 1930-40 average, and most of these cases are due to local outbursts, yet diarrhea ranks second to malaria. Although still short of the number of men needed, the Sanitary Corps is making a place for itself, not only in the army camps but also in the combat areas.

Cathodic Protection

Gordon L. O'Brien, Designing Engineer, Bureau of Water, Baltimore, described his experiments on cathodic protection (see WATER WORKS AND SEWERAGE, July 1942, for complete description) and pointed out the following important factors to consider in any system for the protection of corrosion by impressed current. The pH varies across the "cell" (tank) and may be as low as 6.4 at the rod and as high as 8.4 at the shell. The protection is actually afforded by a deposition of calcium carbonate on the shell. Corrosion by waters lacking in calcium salts cannot be prevented so readily by cathodic protection. The current density determines the pH and too much current should not be used or the cathode will corrode by hydrogen and oxygen reactions. The current must be high enough, however, to cause the carbonate to deposit.

In answer to a question, he said that waters low in calcium should be enriched with lime.

Annual Banquet

With Mr. R. J. Stewart, newly elected president, as toastmaster the annual banquet was held with practically a complete attendance of the 161 registrants. Among several guests introduced was Mr. Ezra Whitman, President of the American Society of Civil Engineers. Mr. Whitman told of the way in which the legislative bill was prepared and passed creating the Maryland Dept. of Health. After the introductions a floor show with dancers, singers, mistress of ceremonies and magician was presented. Dancing followed.

Friday Morning Session

In the absence of Mr. Arthur H. Culler, Supt. of Sewage Disposal, of Frederick, Md., Mr. W. R. Walter, City Engr., read the paper on the "Operation of the Municipal Disposal Plant" of that city. Prior to 1937 there were no sewers in this village of 15,000 and general unsanitary conditions existed, including a rat filled garbage dump. Now there are but 200 out of 4,000 homes yet to be connected to the sewers. The paper described the plant and the garbage incinerator which was built at the same time for the purpose of burning dewatered raw sludge cake with the garbage. Incinerator load is mixed in the ratio of 800 lb. of garbage to 500 lb. of sludge. Auxiliary fuel, consisting of corncobs, is needed only for starting operations for the daily 7½ hour burning period and for burning water melons in season. The speaker told of several explosions that had occurred in the furnace, one from a box of powdered floor grindings from a floor finishing machine, and another from unexploded rifle shells mixed in garbage. Insurance is carried. Operating costs are 59.6 cents per capita per year for sewage treatment, and 35.8 cents per capita per year for garbage disposal.

(1) (2) (3) (4) (5)

Water Engineers

(1)Ted H. Kain, Gen. Mgr. Columbia (Pa.) Water Co. (2) James W. Engel, Chief Water Groups, office of Chief of Engrs., Washington, D. C. (3) J. S. Strohmeyer, Div. Engr. Baltimore Bur. of Water. (4) Ellwood Johnson, Engineer of Sewers, Washington, D. C. (5) Leon A. Small, Chief, Baltimore Bureau of Water.

The Hardy Cross Method

Mr. T. F. O'Connor, Office of the Chief of Engineers, War Dept., Washington, presented his **"Rapid Method of Analyzing Flows in Water Distribution Systems."** Mr. O'Connor's most important contribution to the simplification of the Hardy Cross Method for analyzing water

flows (see D. R. Taylor's article on this subject in the Reference Section of this issue) is the development of a single nomograph from which by means of a simple formula and conversion factors make the method vert larger pipe sizes to the equipment length of an eight inch size. A number of slides showing examples were projected on the screen but suffered from lack of readability because of small print size.

Mr. Roy Ritter, of Whitman, Requardt and Smith, pointed out that the Hardy Cross Method takes the guesswork out of solving problems of water distribution systems, and Mr. O'Connor's one graph and conversion factors makes the method easy to use. He was also high in praise of the recently published Taylor modification, reprints of which he distributed.

Sanitary Manpower Problems

According to Capt. Clarence W. Klassen, Committee on Sanitary Engineering, W. M. C., the sanitary engineering problems of this country are well defined. There is a shortage of men because of the high needs for such trained men in health departments, the sanitary corps, camps, air fields, tank forces, military governors in the operation of military water and sewage plants, and the public health service, as well as the continuance of operation of civilian water supplies and sewerage disposal systems. (Capt. Klassen's complete paper was printed in the May issue of WATER WORKS AND SEWERAGE.)

Distribution System Valves and Emergency Service

Thomas M. Latimer, Chief Valve Inspector, District of Columbia Water Dept., told about the "Preparation of a Valved Distribution System for Emergency Service," mentioning the possibility of many simultaneous breaks and the need for valve service under such conditions. Fires probably will occur at the same time and fire equipment and chlorinators are useless if valves won't work. Therefore, it is important that valves be in good working order, that accurate records and information be available on all valves in the system, and that there be men available who have a thorough knowledge of the peculiarities of the system. The importance of these men who cannot be trained in a year is a factor that should be brought to the attention of local selective service boards.

Among the several suggestions made by Mr. Latimer were the replacement of old valves with new ones wherever possible within W. P. B. limitations; place new valves in strategic locations to allow for the best possible service under all emergency conditions; provide dual feed lines where possible but make sure that such dual lines are not in the same or adjacent streets; supplement valve tools and equipment; and prepare good valve location maps.

The meeting adjourned promptly but from the number of registrants who thronged the hotel lobby for some time after the meeting was over it appeared that there were many who were reluctant to leave. Exchanges of ideas were much in evidence among those remaining and there were many who wanted to "get Capt. Klassen's ear," each with his own problem.

78 FIRMS TO EXHIBIT AT CLEVELAND CONFERENCE

At the Second Wartime Conference of the A.W.W.A. in Cleveland, June 15-18th, seventy-eight firms have taken exhibit space.

This number has far exceeded expectations of the Water & Sewage Mfrs. Assn., and this fact presages an excellent meeting.

The following firms are to be represented:

Acadia Synthetic Products Div.
American Cast Iron Pipe Co.
American City Magazine.
American Rolling Mill Co.
American Smelting & Refining Co.
American Well Works.
Badger Meter Mfg. Co.
Barrett Co.
Birch Mfg. Co.
Buffalo Meter Co.
Builders-Providence, Inc.
Calgon, Inc.
Central Foundry Co.
Centriline Corp.
Chapman Valve Bag Co.
Chem-Feeds, Inc.
Chicago Bridge & Iron Co.
Clow & Sons, James B.
Darco Corp.
Dearborn Chemical Co.
De Laval Steam Turbine Co.
Deming Co., The
Dorr Co., Inc., The
Dresser Mfg. Co.
Electro Rust-Proofing Co.
Engineering News-Record.
Everson Mfg. Co.
Flexible Underground Pipe Clean. Co.
Ford Meter Box Co.
General Paint Corp.
Graver Tank & Mfg. Co.
Hanks Co., The Fred W.
Hays Manufacturing Co.
Hersey Manufacturing Co.
Hydraulic Development Corp.
Industrial Chemical Sales Div.
W. Pa. Pulp & Paper Co.
Infilco, Inc.
Johns-Manville.
Kennedy Valve Mfg. Co.
Layne & Bowler, Inc.
Lead Industries Association.
Leadite Co., The.
Limestone Products Corp.
Lock Joint Pipe Co.
Metallizing Co. of America.
McWane Cast Iron Pipe Co.
Monsanto Chemical Co.
National Meter Co.
National Water Main Cleaning Co.
Neptune Meter Co.
Omega Machine Co.
Permutit Co., The.
Phoenix Meter Corp.
Pitometer Co., The.
Pittsburgh-Des Moines Steel Co.
Pittsburgh Equitable Meter Co.
Pollard Co., Inc., Joseph G.
% Proportioneers, Inc. %
Public Works Magazine.
Rensselaer Valve Co.
Ross Valve Mfg. Co., Inc.
Rusta-Restor Div.
Johnson and Jennings Co.
Simplex Valve & Meter Co.
Smith Mfg. Co., A. P.
Sparling, R. W.
Stuart-Brumley Corp.
Thomson Meter Corp.
United States Pipe & Foundry Co.
Vogt Mfg. Co.
Wailes Dove-Hermiston Corp.
Wallace & Tiernan Co.
Water Works Engineering.
Water Works & Sewerage.
Wood Co., R. D.

"PATENTS AT WORK"

The United States Government, through the Office of Alien Property Custodian, now holds about 50,000 patents formerly owned by residents of enemy or enemy-occupied-and-controlled countries. Early this year a 25-page pamphlet was issued by the Allied Property Custodian to provide American industry with a brief outline of the policies which have been adopted for the administration of these patent holdings, which cover inventions in every field of science and represent millions of dollars spent for investigation.

The Alien Property Custodian has the function of taking title to or controlling property and patents in the United States, owned or controlled by enemy nationals and in certain cases by non-enemy foreign nationals. Such property includes business enterprises of all kinds, real property, trusts, estates, ships, copyrights, trade marks and miscellaneous property. The office of Alien Property Custodian takes title to or supervision over foreign or enemy property in order to prevent it from being useful to the enemy and in order to administer it in the interest of the United States.

National policy clearly dictates that this Government should seize, and turn to the advantage of its citizens, rights to the discoveries of our present enemies which have been protected in this country by United States patents. Accordingly, title to these patents and patent applications owned by the enemy is being vested in the name of the United States Government. Vested patent applications are being published, making these inventions part of the common body of knowledge of the community as well as assisting and encouraging research along similar lines in this country. Licenses are being granted for the life of the patents. However, no *exclusive* licenses will be granted. This fund of knowledge controlled by the Alien Property Custodian can be set to work to destroy the military might of its creators and to help produce material which in post war years will form a strong bulwark of the free world for which we now struggle.

In quite a different sense the Custodian has a great measure of responsibility toward the nationals of enemy occupied territory who are now unable to prosecute patent applications or to administer patents issued to them.

As a basis for the administration of the patent program of the Alien Property Custodian, extensive investigation was made of foreign ownership of U. S. patents and all live patents ever issued in the name of a foreign national have been listed.

The wise utilization of these patents now held by the government imposes three responsibilities on the Alien Property Custodian and on American business. First, the government must make all such patents available to serve American industry; second, encouragement of further research on these inventions must be engendered; third, these vested enemy patents must be made available forever to American industry.

Each vested patent and patent application has been listed by title under the standard Patent Office classifications of patents. These classified lists may be obtained for a small fee to cover printing, by writing to the Office of Alien Property Custodian, Chicago, Ill., and ordering by class number, the classes in which you are interested.

The government proposes to cooperate with American industry to see that adequate research on these inventions is undertaken and full information on the policy is being circulated among research centers and educational institutions. These patents will not be sold or leased. Inventions covered by these enemy patents will be made the permanent property of the American people and through freely granted licenses they will be incorporated in the American industrial machinery.

American business likewise has a responsibility to employ these inventions in every phase of the war effort and to develop them as an aid in building a sound post war economy. Industry must also work toward the constant improvement of these inventions.

The patent licensing policy of the Alien Property Custodian has been designed to aid in the winning of the war and to permanently enlarge the national production in the post-war period. This policy is set forth in the booklet, with complete information as it concerns (1) enemy patents and applications not exclusively licensed to American industry; (2) non-enemy patents and applications not exclusively licensed to American industry; (3) patents exclusively licensed; (4) restrictive provisions in existing licenses; (5) protection afforded licensees, and (6) patents held by corporations supervised or controlled by the Alien Property Custodian.

Where exclusive licenses are not already outstanding to American industry, the Custodian will issue licenses under vested patents in accordance with certain terms and conditions. Where non-exclusive licenses are already outstanding to American concerns or individuals, others will be licensed, on the basis of the same terms when application is made.

Where exclusive licenses are not already outstanding to American industry, licenses under vested patents formerly standing in the name of nationals of enemy-occupied territories will be issued on terms similar to those for comparable enemy patents. Subject only to the consideration that nothing hinder the war effort, the licensing policy of the Custodian's Office will not disturb *bona fide* American interests in vested enemy and non-enemy patents and applications.

Licensees under vested patents will have full protection of the First War Powers Act of 1941. Full and adequate procedure will afford direct recourse to the Custodian for any persons, not enemy nationals, claiming ownership or interest in patents vested in the Alien Property Custodian's office.

When the Alien Property Custodian vests or supervises corporations domiciled in the United States, which have patent rights, a different patent and patent licensing policy will be followed by that office. Patents so held or vested will be administered by their managements but in accord with the broad policies laid down by the Custodian. By this general licensing policy the Government offers to the American people a vast fund of research represented by the patents vested under the President's war powers.

The pamphlet contains explicit information on "How to obtain a license under a patent controlled by the Alien Property Custodian" and "Instructions for preparing a letter of application for a license." An index of vested patents is included in the pamphlet. Among other thousands, it lists 6 patents on sewerage and 171 patents on water.

*An abstract of *"Patents at Work"* issued by Leo T. Crowley, Alien Property Custodian.

"Write the Office of Alien Property Custodian, Chicago, for classified lists of vested patents and patent applications. All classes are sold for 10 cents except Patent Office Classes 23, 74, 88, 95, 123, 78, 179 250, and 260 which are 25, cents each. Complete catalog without binders, $5. Printed copies of vested patents and drawings and specifications of vested patent applications may be secured from the Commissioner of Patents, Washington, D. C., for 10 cents each."—G. E. S.

Vested Patents on View

A library of vested patents held by the Alien Property Custodian has been opened at 120 Broadway in New York City. These "libraries" of patents will contain all the patents vested from the enemy and other aliens.

It is our understanding that the Alien Property Custodian is establishing these libraries in several of the principal cities.

WATER AND SEWAGE PATENTS

A Digest

By JULIAN F. SMITH
Associate Editor
HOOKER SCIENTIFIC LIBRARY
CENTRAL COLLEGE
MISSOURI

Water Patents

SILICA REMOVAL. Sebastien O. A. Fiedler and Geza V. Austerweil (vested in the Alien Property Custodian). U. S. 2,313,194, Mar. 9. Removing silica from water by contact with silicate-free calcium aluminate.

METER. Richard C. Bradley. U. S. 2,313,511, Mar. 9. A meter in which the liquid chamber is sealed from the register chamber, has in the liquid chamber a propeller actuated by a gearless variable speed transmission.

WATER PURIFIER. W. H. Green (to Infilco, Inc.). U. S. 2,314,977, Mar. 30. Apparatus in which raw water and a reagent are fed to a basin at a point near the inlet to a reaction chamber, and means for circulating the water in the basin and reaction chamber rapidly enough to prevent sedimentation.

HEATING SWIMMING POOLS. Edward W. N. Boosey. U. S. 2,315,-184, Mar. 30. Discharging heated water into a swimming pool at spaced points near the bottom, in such a way that the jets serve to inject warm water from near the top of the pool into the streams discharging into the pool near the bottom.

WATER SOFTENER. Arthur L. Riche. U. S. 2,215,223, Mar. 30. In a series of base-exchange softener units the effluent from each unit is conducted to a tester which automatically indicates the need for regeneration when a unit is spent.

CHLORINE FEED. Roy B. Everson. U. S. 2,315,512, April 6. A device for feeding chlorine into a liquid stream has a tower to which a liquid and chlorine gas are fed, and a conduit in the tower which governs the flow of chlorine according to the liquid level.

CLARIFYING WATER. A. W. Ralston and W. O. Pool (to Armour and Co.). U. S. 2,315,734, April 6. Removing unfilterable turbidity from water by flocculation with primary or secondary alkylamines or water-soluble salts thereof, the alkyl groups being hexyl or higher.

GRAVITY FILTRATION. E. G. Duden (to Scaife Co.). U. S. 2,317,-847-8, April 27. Apparatus for precipitating impurities from raw water near the bottom of a reaction tank containing an open top sludge collector; and a hot process gravity filtration apparatus for continuously supplying treated water at variable rates.

BOILER WATER. P. G. Bird, W. Evans, C. Harmon and J. R. Salvesen (to Marathon Paper Mills Co. and National Aluminate Corp.). U. S. 2,318,663, May 11. Boiler water is treated with a sulfite and a ligninsulfonate or sulfite waste liquor in order to prevent caustic embrittlement of boilers.

Sewage Patents

FILTER BED CLEANERS. Chas. E. Fraser. U. S. 2,315,252-3-4, Mar. 30. A scraper for removing dirt from the channel beneath a downflow filter bed; a device for closing off a selected area of a filter bed and washing the filter medium in that area; and such a cleaner equipped with a device for raising material from the filter bed to the washer.

SEWER CLEANER. Frank Surges. U. S. 2,313,599, Mar. 9. A pipe cleaner having a fixed and an adjustable stop on a shank, with a tool carrier sliding along the shank between stops and with spring-controlled prongs which are adjustable to different pipe sizes.

SEWAGE DISTRIBUTOR. Chas. Yeomans (to Yeomans Bros. Co.). U. S. 2,314,182, Mar. 16. A rotary distributor in which sewage flows from a hollow central column into radially extending distributing arms has an adjustable leveling support for setting the column in the true vertical position.

SEWAGE DISTRIBUTOR. Arthur A. Page (to Albert M. Marshall). U. S. 2,314,423, Mar. 23. A distributor for spreading sewage over a trickle filter has radial arms fitted with discharge nozzles which impart centrifugal action so that the nozzles are self-cleaning and the sewage is discharged in a fine spray.

SLUDGE DIGESTION. H. Bach (to Infilco Inc.). U. S. 2,315,577, April 6. Digesting sludge first with mesophilic micro-organism up to a peak of gas production, then with thermophilic organisms.

CLEANING TRICKLE FILTERS. Max Levine (to Iowa State College Research Foundation). U. S. 2,317,782, April 27. Removing excess biological film from the coarse-grained aggregate of a trickle filter bed by backflow washing while blowing air through the filter bed.

SEDIMENTATION TANK.. M. B. Tark (to Link-Belt Co.). U. S. 2,318,436, May 4. A settling tank has a scum hopper and trough and a skimming device for transferring scum to the hopper.

TREATING BLACK LIQUOR. Chas. J. Brockman. U. S. 2,318,919, May 11. Rendering sulfate pulp black liquor harmless to streams by acidifying, diluting with water and adding lime.

SEWER CLEANER. Geo. A. Smith. U. S. 2,320,309, May 25. A cleaner for sewers has a drum with a cage-like periphery, rotatably mounted in a frame and supported by bars in a sleeve-like formation.

Incorporated 1850

Pennsylvania Salt Manufacturing Co.

Manufacturing Chemists.

Widener Building

Philadelphia

Leonard T. Beale
President

February 13, 1943

The Honorable Henry L. Stimson,
Secretary of War,
War Department,
Washington, D. C.

My dear Mr. Secretary:

You are faced today with responsibilities that are far greater than those which have ever before confronted a Secretary of War. Our armies are fighting in a worldwide struggle and you must plan in terms of global war.

While most Americans realize what that means in general terms of troop movements and supply lines, we believe that few people have any conception of the multitude of other important problems you must solve.

For example, the proper sanitation of water supply and sewage in army camps at home and abroad is vitally important in protecting the health of our armed forces. We are glad to say that this is a problem in which we are able to provide direct and effective aid.

For many months past we have been supplying the army with large quantities of Perchloron, an unusually stable chlorine compound, used in the purification of drinking water and for other measures of safeguarding health.

While this is only a comparatively minor contribution to the success of a great plan, we are proud to make it -- and to cooperate in this way in the solution of one of your problems.

Yours for Victory,

Leonard T. Beale

When Johnny comes sailing H

will your Plans for Construction be ready?

This advertisement is addressed to men who are responsible for water supply, gas and sewage works maintenance and construction. For these men have a tremendous opportunity to be of service to the nation during the most critical period of the post-war years: when our soldiers are sailing home again; and when our nation is changing over from an Arsenal of Democracy to the world's greatest producer of the products of peace.

War-deferred water supply, gas and sewage works construction – postponed repairs, replacements and extensions – already adds up to a vast backlog of man-hours of employment. Such employment is quick employment, local and throughout the country; and a quick stimulant to many industries. For example, seven industries – large employers of labor – are involved in the production, transportation and laying of cast iron pipe. Quick employment will be what is needed because Industry cannot convert overnight to peacetime production. Quick employment means that plans must be ready – complete working plans – when the war is over. So the work can start—so we can welcome our soldiers with jobs.

* * *

We know that plans are afoot – but we submit this reminder to all concerned – that early employment is of the utmost importance and that this depends on all possible plans being ready for proposals and the work to be started. Work vital to public health and safety.

* * *

Any of the members of this Association will furnish promptly information and advice in the preparation of specifications taking full advantage of the greater economy and efficiency of cast iron pipe made in accordance with the new A. S. A. Law of Design* – pipe scientifically designed for your specific service requirements.

**** Send for booklet entitled "Manual For The Computation Of Srength And Thickness Of Cast Iron Pipe — Approved by American Standards Association" explaining the principles and methods which are the basis of the new A. S. A. Law of Design.***

HOME AGAIN...
RESEARCH ASSOCIATION, CHICAGO
NO. 1 TAX SAVER

COMMINUTORS FOR EXISTING SEWAGE PLANTS ELIMINATE MANUAL LABOR, HEALTH HAZARDS AND NUISANCE IN HANDLING SEWAGE SCREENINGS

Through Automatic, Subsurface Screening and Cutting of All Coarse Matter in Sewage

Comminutors Are Being Installed in All Sizes and Types of Sewage Plants, Pumping Stations and Outfall Sewers

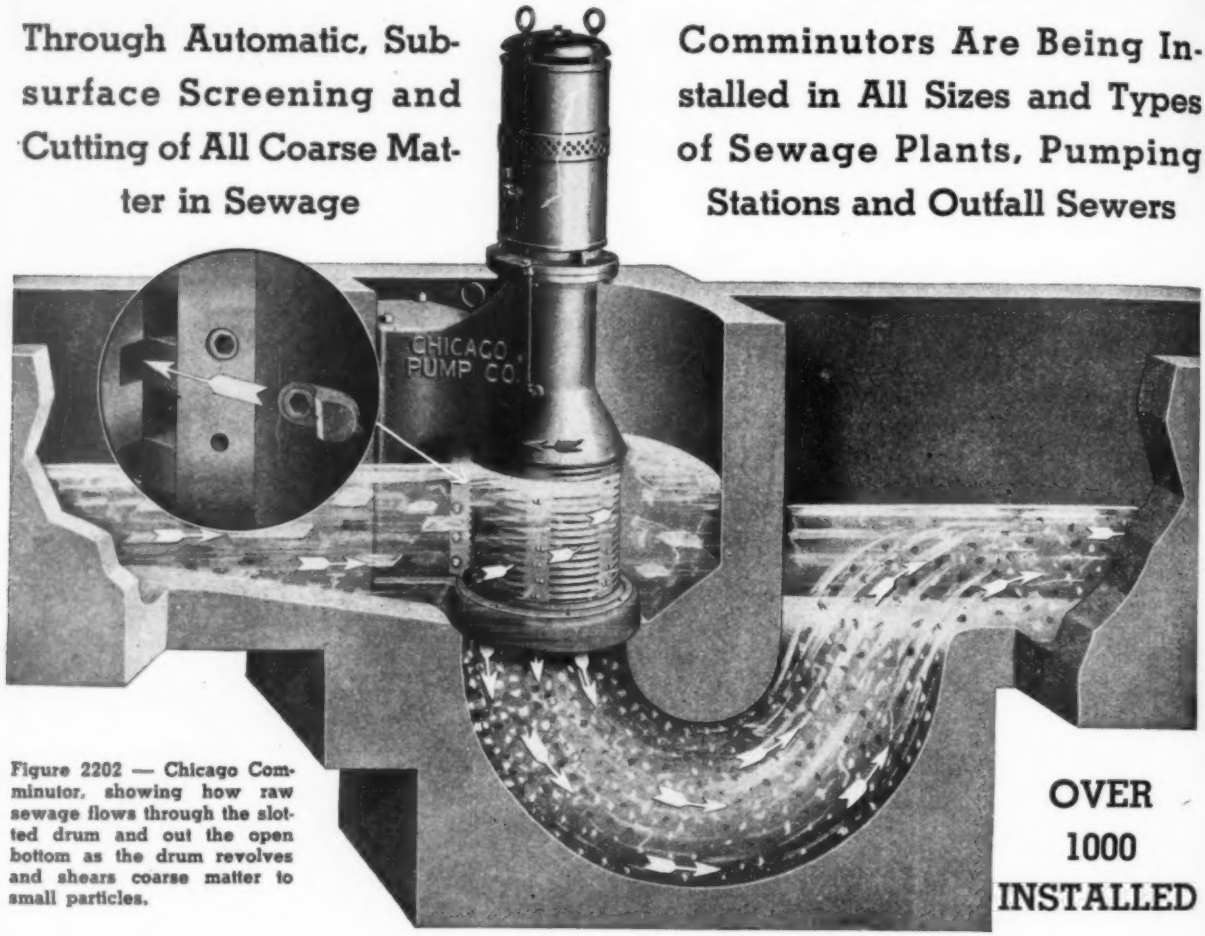


Figure 2202 — Chicago Comminutor, showing how raw sewage flows through the slotted drum and out the open bottom as the drum revolves and shears coarse matter to small particles.

OVER 1000 INSTALLED

SEWAGE PLANTS: All sizes and types of existing sewage plants are installing Comminutors in the raw sewage channel to eliminate handling screenings. Comminuted matter (sheared, small particles passing a maximum drum slot width of ⅜") completely settles out in the primary settling tank and is pumped to the digester with the raw sludge.

PUMPING STATIONS: Comminutors are being installed in many existing pumping stations for protection against pump clogging. Comminuted raw sewage can readily be handled by ordinary sewage pumps without clogging.

OUTFALL SEWERS: Where disposal is by dilution, Comminutors are installed in the outfall sewer to prevent shoaling of unsightly matter on beaches, shores or banks. The comminuted solids settle rapidly to the bottom of the body of water.

COMPLETE DIMENSIONED LAYOUTS AND SEWER FLOW CURVES ARE IN BULLETIN 185-A

CHICAGO PUMP CO. SEWAGE EQUIPMENT DIVISION

2336 Wolfram Street, CHICAGO, ILL.
Phone BRUnswick 4110

VACUUM—CONDENSATION—CIRCULATING—BILGE
FIRE — HOUSE — SEWAGE — SCRU-PELLER PUMPS
AERATORS — COMMINUTORS — SAMPLERS

REPRESENTATIVES THROUGHOUT THE UNITED STATES AND FOREIGN COUNTRIES

THE SELECTION OF MAIN LINE METERS

With a Set of Charts Designed to Simplify the Problem

By J. C. THORESEN
Engineer
BUILDERS-PROVIDENCE, INC.
PROVIDENCE, R. I.

The Author

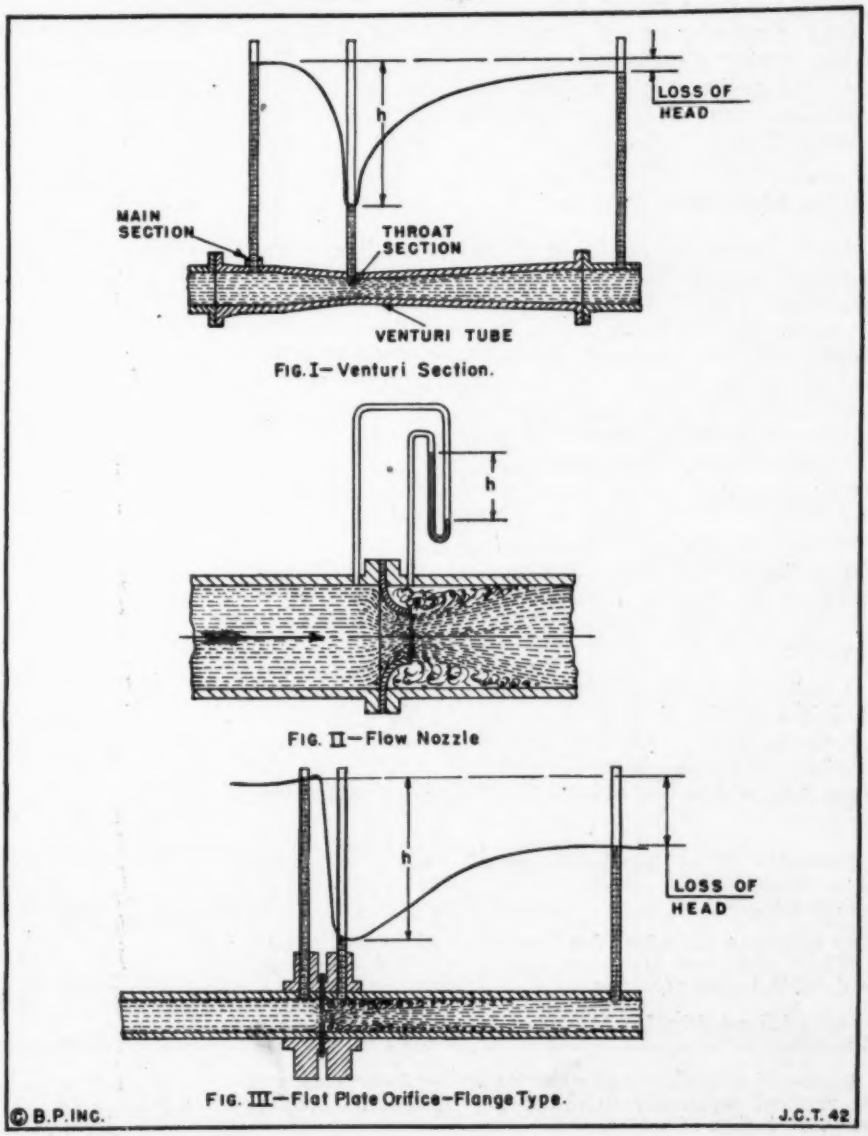
IN the selection of suitable meters for main gravity and pump discharge pipe lines, price is too frequently the sole determining factor, whereas a closer examination of the proposals may demonstrate that such a decision would be definitely improper from an economic standpoint. This does not assert that the lowest priced equipment is never warranted, but simply that experience has repeatedly emphasized the importance of making an evaluation of design and specifications. These include the reputation of the meter; its anticipated life; materials, workmanship and finish; probable cost of maintenance; character of information furnished, such as size of dials and charts, uniformity of graduations, whether direct reading in units of flow or indirect in nominal values or differentials; and, most important, the friction loss induced. It is not the purpose of this paper to comprehend all of these, but to devote the discussion to the last mentioned, the friction loss, resulting in loss of pressure, or power, or both, occasioned by the insertion of the flow measuring element in the pipe line.

For gravity lines under low heads, the friction loss of the proposed meter should be carefully studied to determine whether objectionable in its effect on the hydraulic gradient. In a pump discharge line, friction loss alone may not be of significance, but when considered together with pipe line size and hours of operation, the combination of these three factors may be of great monetary importance in a 12 months' period.

In general, main line meters operate on the inferential principle: that is, the flow rate is "inferred" from the difference in pressure induced by a "restriction" placed in the pipe line and transmitted to the recording instrument, through which no flow occurs. It is readily appreciated by all water works men that elbows, tees, partly closed valves or other fittings add to pipe line friction loss and must be reckoned with in the design of the system. So it is with meters. Whether water is first lifted to a reservoir or pumped directly through the pipe line, the additional load is reflected back upon the pumps, requiring provision for more horsepower than would otherwise be required, and power always costs money.

Forms of Differential Producers

There are only a few forms of "differential producers" for insertion in pipe lines. Of these, the Venturi Tube and Orifice Plate are by far the most widely employed. They are entirely unlike in their construction.



Figs. I, II and III—Three Forms of Differential Producers for Main Line Metering.

ers" for insertion in pipe lines. Of these, the Venturi Tube and Orifice Plate are by far the most widely employed. They are entirely unlike in their construction.

The Orifice (Fig. III) is essentially a flat plate between flanges of the main pipe. As the flowing water approaches the Plate, the stream lines undergo an abrupt (nearly 90 degree) change in direction; then, after passing through the Orifice opening, start to expand again until finally the pipe line is completely filled. As would be expected, there is considerable turbulence in the surrounding annular space on both sides of the Orifice occasioning a relatively high over all pressure head loss.

The Venturi Tube

The Herschel Standard Venturi Tube (Fig. I) is of "streamlined" proportions. It forms a section of the pipe line. As the flow progresses from the inlet section there is a rapid acceleration of velocity with decreasing pressure until the "throat" is reached, where the speed of flow may be ten or more times as great as at the inlet. After passing the throat, the velocity is decelerated through a gently expanding outlet cone, with consequent gradual regain in pressure. The velocity distribution is equal across the throat and the rate of flow is based upon the throat area. Throughout this interchange of velocity and pressure, there is wall guidance of the flowing stream and turbulence is avoided. For this reason the standard Venturi Tube has definite advantage over the Orifice in the important matter of pressure loss.

Orifice Plates and Nozzles

Fig. II illustrates one form of the "Nozzle", of which there are various designs. The type shown is slightly better than the Orifice in pressure loss characteristics, but not enough to warrant separate consideration. The graph (Fig. IV) shows the comparison of friction loss for the three differential producers mentioned. The steep slope of the two upper curves for the Orifice and Nozzle are in sharp contrast to the Venturi curve: in the Venturi the friction loss changes but a few per cent for a wide range of the throat diameter to inlet diameter ratio (d_2/d_1) in contrast with the other two devices. It will be observed that the friction loss is in per cent of the Orifice or Venturi differential head (i.e.—head at inlet minus head at throat) which may reach a maximum of 10 to 20 feet of water, if not more, for accurate metering.

A reduction in the unrecoverable loss of head through an Orifice or Nozzle to a value comparable to the Venturi Tube, by increasing the size of the orifice or nozzle opening, also reduces the differential pressure at any given rate of flow and results in a decreased measuring range.

Example: 10-in. Herschel Standard Venturi Tube with 4-in. throat. Rate of flow 1,400 gallons per minute. $d_2/d_1 = 0.4$.

By following directions for Example 3 given on the Rate of Flow Alignment Diagram, Fig. V, we find differential head = 240 inches of water.

Loss of Head, Fig. IV, 11½% of 240 inches = 27.6 inches of water.

Assume that the average meter recording instrument will not respond accurately to changes in differential of less than .010 inches of water.

Minimum differential equals 1.00 inches for performance accuracy of 1% of differential.

Rate of flow varies as square root of differential.

$\therefore$ accurate measuring range of Venturi $= \sqrt{\frac{240}{1}} = 15.5$ to 1 or 1,400 to 90 G.P.M.

For same unrecoverable loss of head of 27.6 inches Orifice Plate opening would be 7.06 inches (approx.) or $d_2/d_1 = .7$.

Differential pressure for 1,400 G.P.M. = 53.4 inches of water.

Loss of Head (Fig. IV) = 51¾% of 53.4 inches of water = 27.6.

Accurate measuring range of Orifice Plate $= \sqrt{\frac{53.4}{1}} =$ 7.3 to 1, about one-half that of Venturi.

Having now established briefly the characteristics of two principal differential producers, let us determine their practical significance by recourse to common problems met in water works practice.

Horsepower is measured in foot-pounds of work performed in a definite time period. If we raise a 50 pound weight a distance of one foot, the work done is 50 foot-pounds. By analogy, if we have 8340 pounds of water (approximately 1000 gals.) per minute flowing through a pipe line and one foot of head is lost by pipe friction, the result is the same as though the water had been raised one foot, or energy is being expended at a rate of 8340 foot-pounds per minute.

Practical Problems

Two practical problems are cited to illustrate the method of determining the comparative cost of using Venturi Tubes and Orifice Plates.

Problem A

Water pumped through line containing 16 inch Herschel Standard Venturi Tube with 6½ inch throat.

Average rate, 3,700 G.P.M.

Electric-driven pump with overall (wire to water) efficiency of 70%.

Average operating period 15 hours per day for 360 days per year.

Power cost 1½c per K.W.H.

$d_2/d_1 = \frac{6.5}{16.0} = .405$

Using Alignment Chart, Fig. V, Venturi differential = 240 inches = 20 feet of water.

From Fig. IV, corresponding friction loss = 11½% of 20 feet = 2.3 feet.

3,700 G.P.M. × 8.34 = 30,858 pounds.

Energy Loss = 30,858 × 2.3 = 70,973 foot-pounds per minute; and $\frac{70{,}973}{33{,}000} = 2.15$ horsepower.

Equivalent electrical loss = 2.15 × .746 = 1.605 kilowatts.

Corrected for motor and pump efficiency $\frac{1.605}{.70} = 2.29$ KW.

Cost of power per year
= Hours × KW. Loss × Cost per K.W.H. = $185.00
(360 × 15) × (2.29) × (.015) = 1

From Fig. V, an Orifice Plate for same maximum flow would have an opening 8.25 inches diameter.

$d_2/d_1 = \frac{8.25}{16} = .515.$

Loss through Orifice = 71% of differential = .71 × 20 = 14.20 feet.

HP. Loss $= \frac{14.20}{2.3} \times 2.15 = 13.3.$

Cost of Power per year $= \frac{13.3}{2.15} \times \$185.00 = \$1{,}145.00.$

Cost of 16 inch Venturi Tube	$640.00
Cost of 16 inch Orifice Plate and Flanges	65.00
Difference	$575.00

Saving in power consumption by using the Venturi Tube, $1,145.00 — $185.00 = $960.00 per year.

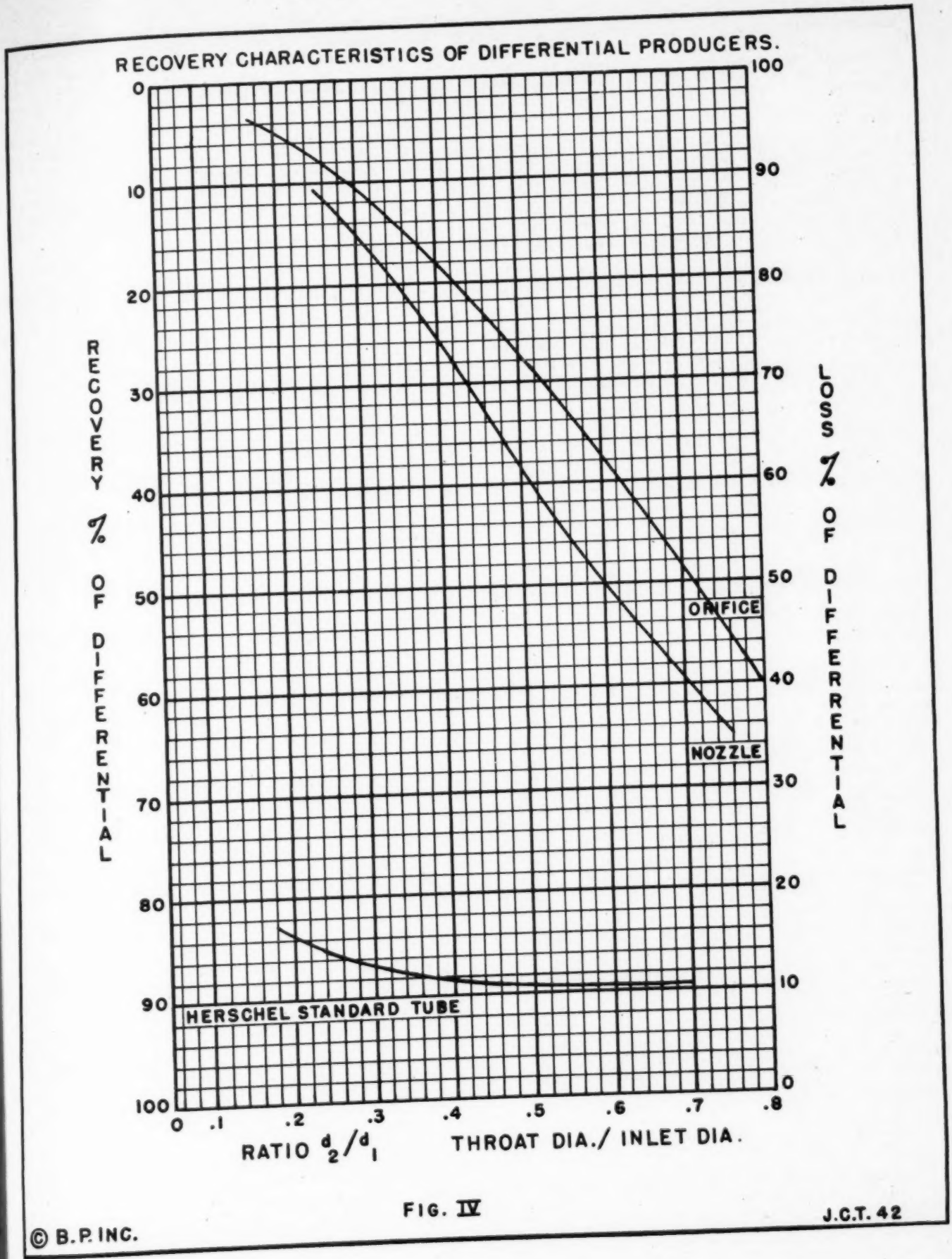


Fig. IV—Recovery Characteristics of the Venturi Tube, Nozzle and Orifice.

Omitting depreciation, $\frac{960}{575} = 167\%$ return on investment.

Conclusion: In comparison with the Orifice, the Venturi Tube would pay for itself in about six months and should be selected.

Problem B

Motor-driven pump operating 15 hours per day, 350 days per year = 5,250 hours per year.
Discharge line, 4.00 inches.
Wire to water efficiency, 60%.
Cost of power, 2c per K.W.H.
Pump discharge average rate, 100 G.P.M.
4.00 inch Venturi Meter designed for a maximum of 350 G.P.M.; throat diameter, 2.00 inch.

$d_2/d_1 = \frac{2.00}{4.00} = .50.$

Following the procedure outlined in "Problem A" and using Alignment Chart, Fig. V, differential pressure across the Venturi connections for 100 G.P.M. is 18¾ inches water.
From Fig. IV, friction loss = 10½% of 18¾ inches = 1.97 inches or .164 feet.

$$\text{H.P. loss} = \frac{100 \times 8.34 \times .164}{33{,}000} = .00415.$$

Substituting an Orifice Plate for the Venturi Tube the 18¾ inches differential (Fig. V) gives Orifice opening of 2.49 inches or $d_2/d_1 = \frac{2.49}{4.00} = .622.$

From Fig. IV, friction loss = 60.5% of 18¾ inches = 11.32 inches or .945 feet.

$$\text{H.P. loss} = \frac{.945}{.164} \times .00415 = .024.$$

.024 — .00415 = .0199 excess of H.P. loss of Orifice over Venturi.
.0199 × .746 = .0148 K.W.
Corrected for pump efficiency,

$$\frac{.0148}{.60} = .0247 \text{ K.W.}$$

Difference in cost of power per year of operation = cost per K.W.H. × electrical loss × hours of operation = .0199 × .0247 × 5,250 = $2.58.

Cost of 4 inch × 2 inch Venturi Tube	$125.00
Cost of Orifice Plate and Flanges	30.00
Difference	$ 95.00

Conclusion: On the basis of a saving of power of only $2.58 per year, it is readily apparent that it will take 36 years to pay the increased cost of the Venturi Tube, and therefore, from a monetary viewpoint, the Orifice Plate should be selected.

To simplify the calculations needed for any meter installation a Horsepower Alignment Chart (Fig. VI) has been prepared. It is easily used and the results are accurate to within a few per cent. Its application to the two problems calculated in the preceding paragraphs is illustrated:

Problem A

16 inch × 6½ inch Venturi Tube compared with 16 inch Orifice Plate having 8.25 inch opening.
Flow Rate, 3,700 G.P.M.

(1) For the Venturi Tube $d_2/d_1 = \frac{6.5}{16.0} = .406$

For the Orifice Plate $d_2/d_1 = \frac{8.25}{16.0} = .515$

(2) From Fig. VII, "Correction Factor" for the Venturi Tube is .992; for the Orifice Plate .783.

(3) To obtain the "Inlet Diameter Corrected for Ratio" for the Venturi Tube or Orifice, multiply the throat diameter or Orifice opening by correction factor × 2. For the Venturi Tube, 6.2× .992 × 2 = 12.89. For the Orifice Plate 8.23 × .78 × 2 = 12.88. Theoretically, these two products should be exactly the same; their close agreement checks the accuracy of the work.

(4) From the point 12.89 on the Corrected Inlet Diameter Scale (I) draw a straight line through 3,700 G.P.M. on Rate of Flow Scale II. Extend this line until it intersects the Index Line.

(5) From the "Recovery Characteristics" Chart, Fig. IV, the friction loss of a Venturi Tube with d_2/d_1 ratio of .406 is 11.5% of differential; for the Orifice Plate with d_2/d_1 ratio of .515 it is 71%.

(6) From the point previously located on Index Line III of Alignment Chart, draw two lines, one to the 11.5% point on the Loss of Head Per Cent of Differential Scale IV; the other to the 71% point on the same scale.

(7) These two lines cross the Horsepower Scale V and the points of intersection represent the horsepower loss for the Venturi Tube and Orifice, respectively 2.15 and 13.25.

(8) The difference in cost of operation of the two differential producers can be quickly determined by using the following simplified formula:

$$\text{Excess cost of using Orifice Plate over Venturi Tube} = \frac{(HP_o - HP_v) \times K \times T \times C}{E}$$

In which:
HP_o = Horsepower Loss for Orifice Plate.
HP_v = Horsepower Loss for Venturi Tube
K = Conversion Factor, HP to KW = .746
T = Total hours of operation
C = Cost of Power per KWH
E = Wire to water efficiency of pumping unit (motor and pump) usually 50% to 80%.
Substituting the values in Problem A
Excess cost of Orifice

$$= \frac{(13.25 - 2.15) \times .746 \times (3600 \times 15) \times .015}{.70} = \$962.00$$

This corresponds almost exactly with the previously calculated difference in cost of $1,145 — $185 = $960.00.

Problem B

4.0 inch × 2.0 inch Venturi Tube compared with Orifice having 2.49 inch opening. Flow rate 100 G.P.M.

(1) For the Venturi Tube $d_2/d_1 = \frac{2.0}{4.0} = \mathbf{0.5.}$

For the Orifice

$$d_2/d_1 = \frac{\frac{2.49}{4.00}}{4.00} = .622$$

(2) From Correction Factor Chart (Fig. VII) correction factor for Venturi Tube is 1.00 and for Orifice Plate .80.

(3) Inlet diameter corrected for ratio: Venturi Tube 2.0 × 1.00 × 2 = 4; Orifice Plate 2.49 × .80 × 2 = 4.

(4) From point 4 on Corrected Inlet Diameter Scale I, draw a line through the 100 mark on the Rate of Flow Scale II. Extend this to the Index Line III.

(5) From Chart, Fig. IV, friction loss of a Venturi Tube with d_2/d_1 ratio of .50 is 10½% of the differential; for an Orifice Plate with a d_2/d_1 ratio of .622 it is 60.5%.

(6) From the point previously located on Index Line III, of Alignment Chart, draw two lines, one to the 10.5% point on the loss of Head Per Cent of Differential Scale IV and the other to the 60.5% point.

(7) The points of intersection of these two lines with the Horsepower Scale represent the horsepower loss for the Venturi Tube and Orifice, respectively, .0038 and .024.

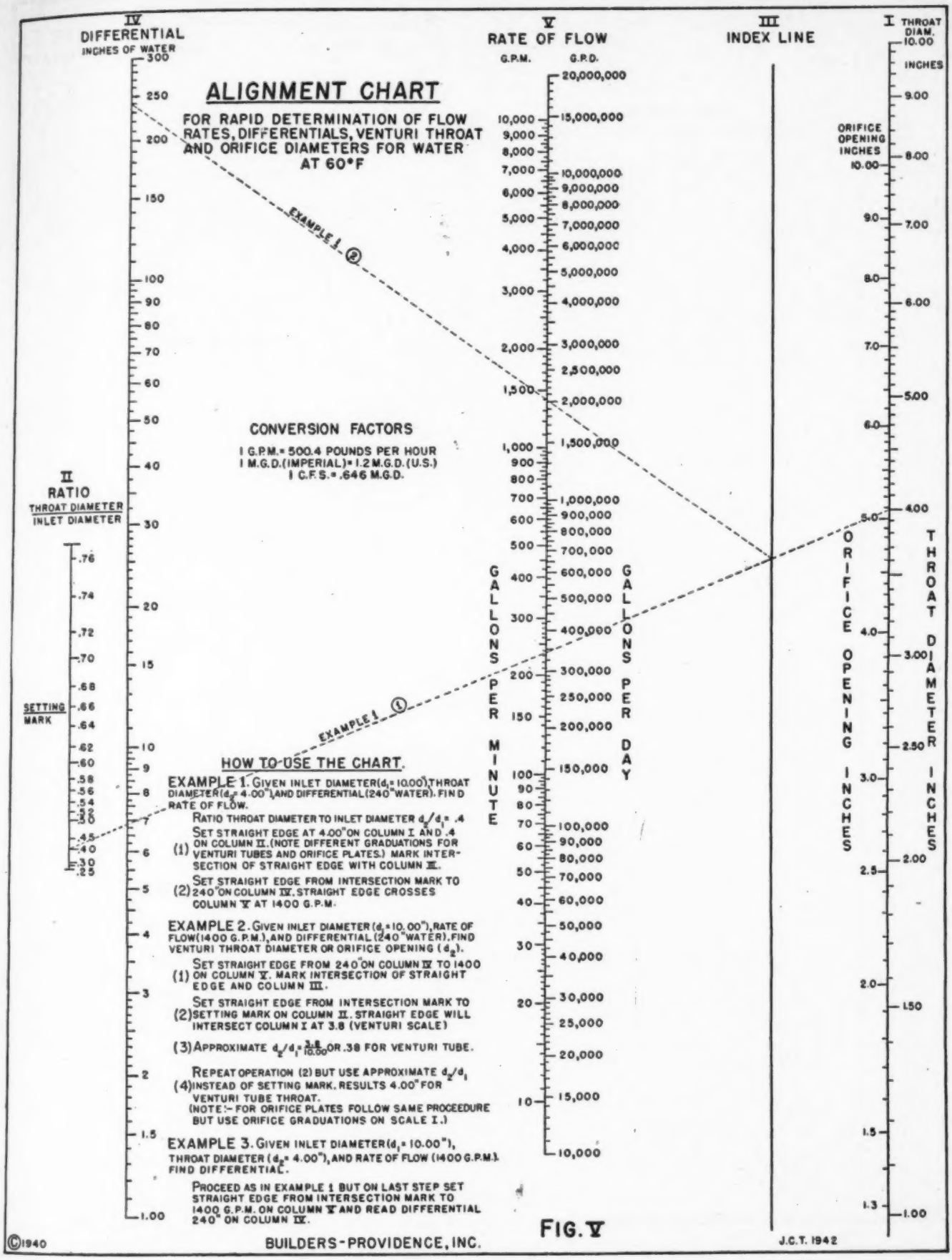
(8) Difference in cost of operation

$$= \frac{(HP_o - HP_v) \times K \times T \times C}{E}$$

$$= \frac{(.024 - .0039) \times .746 \times 5250 \times .02}{.60} = \$2.63$$

This solution by use of the diagrams agrees very closely with the calculated figure of $2.60.

Following the procedure as outlined and with the aid of the several diagrams presented anyone, after a little preliminary practice, can by their use quickly determine the most economical type of meter for any installation under consideration.


ALIGNMENT CHART
FOR RAPID DETERMINATION OF FLOW RATES, DIFFERENTIALS, VENTURI THROAT AND ORIFICE DIAMETERS FOR WATER AT 60°F
IV DIFFERENTIAL INCHES OF WATER
V RATE OF FLOW
G.P.M.
G.P.D.
III INDEX LINE
I THROAT DIAM. INCHES
ORIFICE OPENING INCHES
II RATIO THROAT DIAMETER / INLET DIAMETER
SETTING MARK
GALLONS PER MINUTE
GALLONS PER DAY
ORIFICE OPENING INCHES
THROAT DIAMETER INCHES
EXAMPLE 1
EXAMPLE 2
CONVERSION FACTORS
1 G.P.M. = 500.4 POUNDS PER HOUR
1 M.G.D. (IMPERIAL) = 1.2 M.G.D. (U.S.)
1 C.F.S. = .646 M.G.D.
HOW TO USE THE CHART.
EXAMPLE 1. GIVEN INLET DIAMETER (d_1 = 10.00"), THROAT DIAMETER (d_2 = 4.00"), AND DIFFERENTIAL (240" WATER). FIND RATE OF FLOW.
RATIO THROAT DIAMETER TO INLET DIAMETER d_2/d_1 = .4
(1) SET STRAIGHT EDGE AT 4.00" ON COLUMN I AND .4 ON COLUMN II. (NOTE DIFFERENT GRADUATIONS FOR VENTURI TUBES AND ORIFICE PLATES.) MARK INTERSECTION OF STRAIGHT EDGE WITH COLUMN III.
(2) SET STRAIGHT EDGE FROM INTERSECTION MARK TO 240" ON COLUMN IV. STRAIGHT EDGE CROSSES COLUMN V AT 1400 G.P.M.
EXAMPLE 2. GIVEN INLET DIAMETER (d_1 = 10.00"), RATE OF FLOW (1400 G.P.M.), AND DIFFERENTIAL (240" WATER). FIND VENTURI THROAT DIAMETER OR ORIFICE OPENING (d_2).
(1) SET STRAIGHT EDGE FROM 240" ON COLUMN IV TO 1400 ON COLUMN V. MARK INTERSECTION OF STRAIGHT EDGE AND COLUMN III.
(2) SET STRAIGHT EDGE FROM INTERSECTION MARK TO SETTING MARK ON COLUMN II. STRAIGHT EDGE WILL INTERSECT COLUMN I AT 3.8 (VENTURI SCALE)
(3) APPROXIMATE $d_2/d_1 = \frac{3.8}{10.00}$ OR .38 FOR VENTURI TUBE.
(4) REPEAT OPERATION (2) BUT USE APPROXIMATE d_2/d_1 INSTEAD OF SETTING MARK. RESULTS 4.00" FOR VENTURI TUBE THROAT.
(NOTE:- FOR ORIFICE PLATES FOLLOW SAME PROCEEDURE BUT USE ORIFICE GRADUATIONS ON SCALE I.)
EXAMPLE 3. GIVEN INLET DIAMETER (d_1 = 10.00"), THROAT DIAMETER (d_2 = 4.00"), AND RATE OF FLOW (1400 G.P.M.). FIND DIFFERENTIAL.
PROCEED AS IN EXAMPLE 1 BUT ON LAST STEP SET STRAIGHT EDGE FROM INTERSECTION MARK TO 1400 G.P.M. ON COLUMN V AND READ DIFFERENTIAL 240" ON COLUMN IV.
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BUILDERS-PROVIDENCE, INC.
FIG. V
J.C.T. 1942

Fig. V—Chart for Rapid Determination of Flow Rates, Differentials, Venturi Throat and Orifice Diameters.

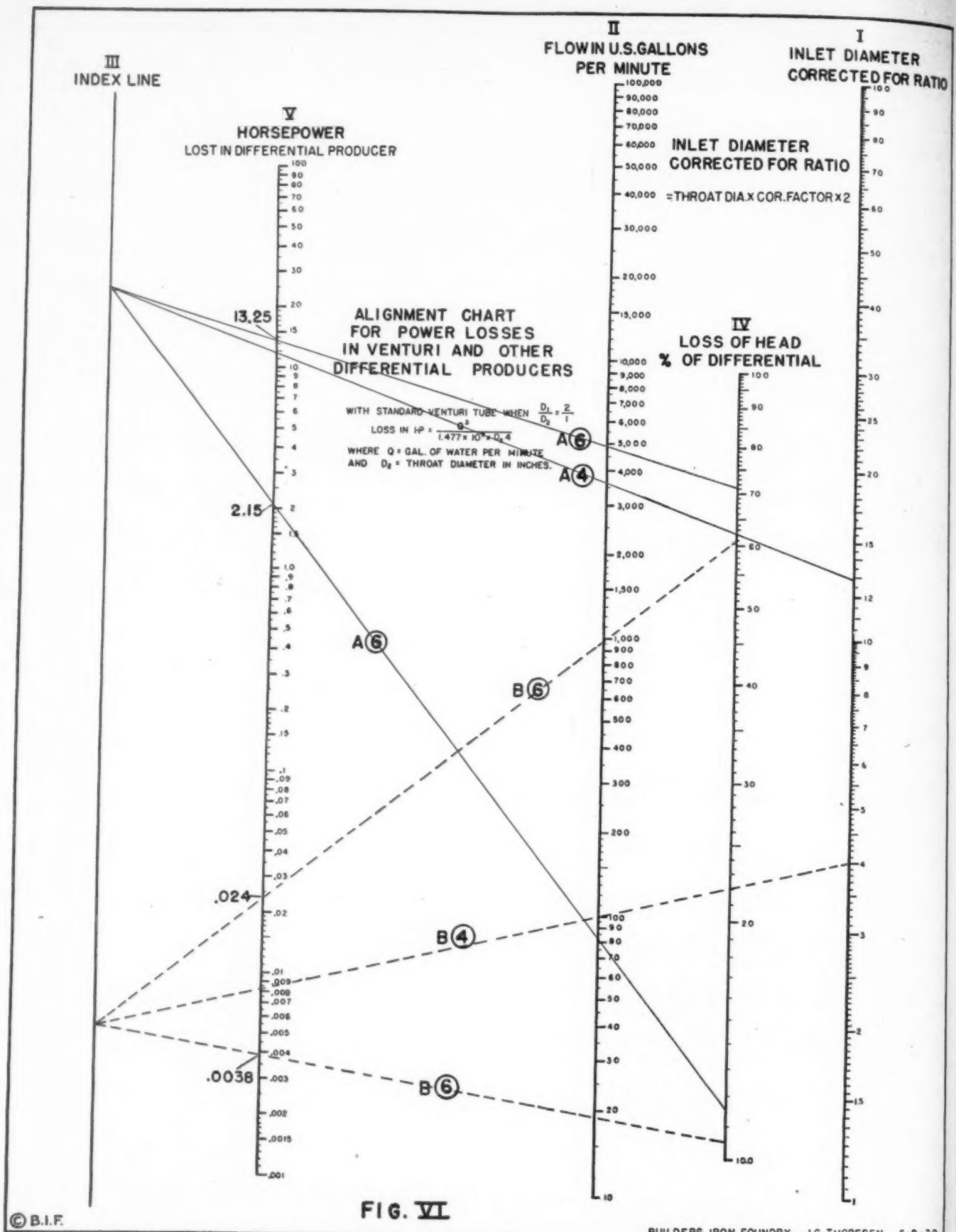

FIG. VI

Fig. VI—Chart for Power Losses Through Venturi Tubes and Other Differential Producers.

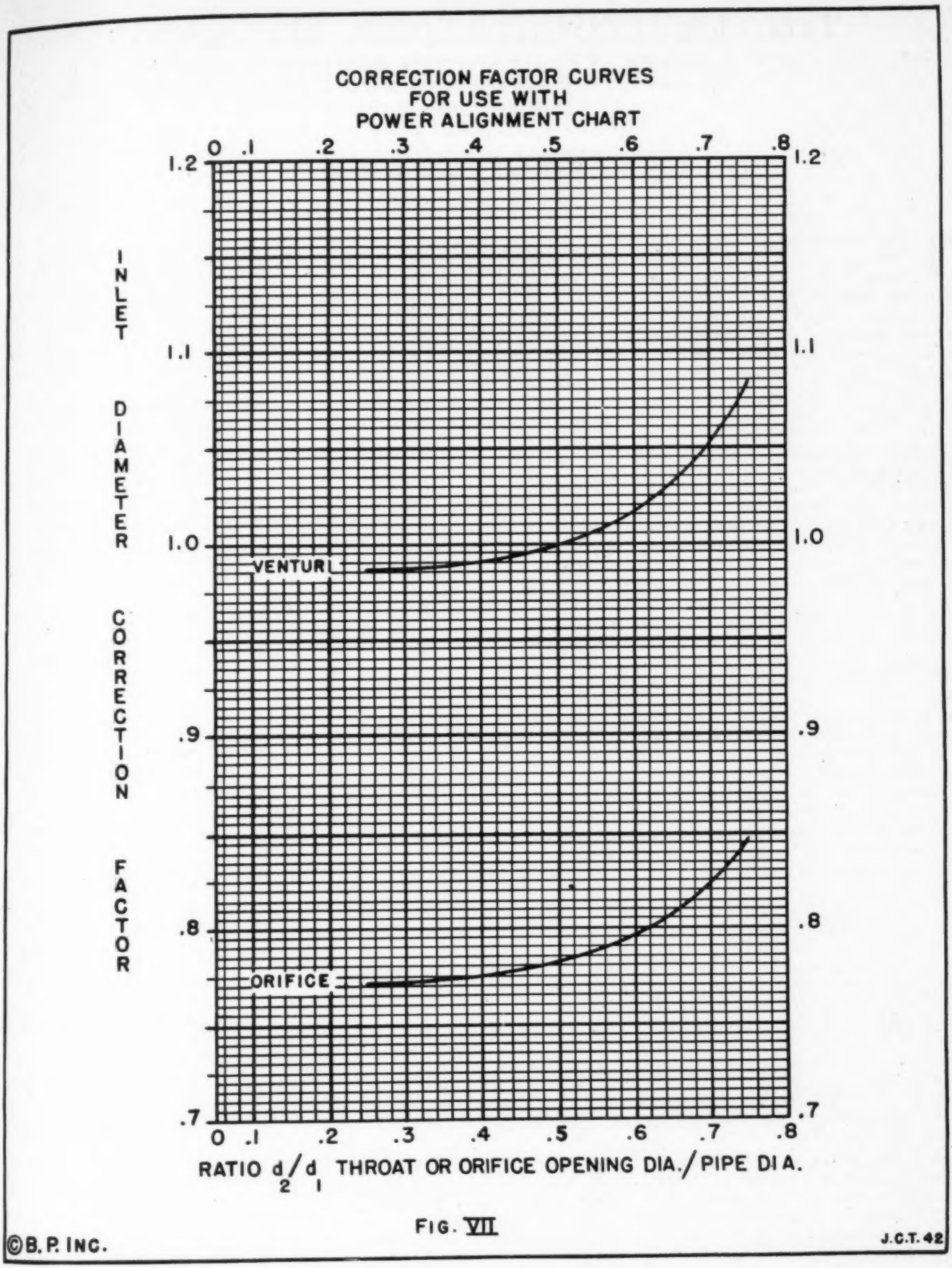

Fig. VII—Correction Factor Curves. (For use with Alignment Chart for Power Losses—Fig. VI.)

THE DETERMINATION OF SAND IN WELL WATER

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CARACAS, VENEZUELA, S. A.

THE determination of the volume of sand in water pumped from deep wells is important for two reasons: first, to ascertain the effectiveness of an artificial gravel wall or of a "natural gravel pack", around the screen or perforated casing, in excluding the sand in the water bearing formations; and second, to ascertain the amount of sand that a well "makes" after its development has been completed. An excessive amount of sand in the water pumped from a well reduces the life and efficiency of a pump, erodes the screen, accumulates in the system of piping and damages meters.

The following method of determining sand in well water was developed by the writer in the water analysis laboratory of the Ministry of Public Works of the Venezuelan Government. A sample of water is collected in a two (2) liter bottle and is given a rotary motion so as to move the sand toward the center of the bottom of the bottle and to form a disk. Standards are prepared from a similar sand by placing in wide mouth bacteriological bottles, of 125 ml. capacity, measured amounts that correspond to 1, 3, 5, 10, 15, 25, 50, 100 and 200 parts per million by volume in two (2) liters of water. Water is then added to about half the heighth of the bottle. For standards of 300, 400, 500 and 600 p.p.m. it is preferable to use bottles of 250 ml. The standards are given a rotary motion to obtain a disk of sand in the center of the bottom of the bottle and the disks are then compared with the disk on the bottom of the bottle of the two (2) liter sample of water. It is essential to select bottles with a smooth, flat bottom of clear glass.

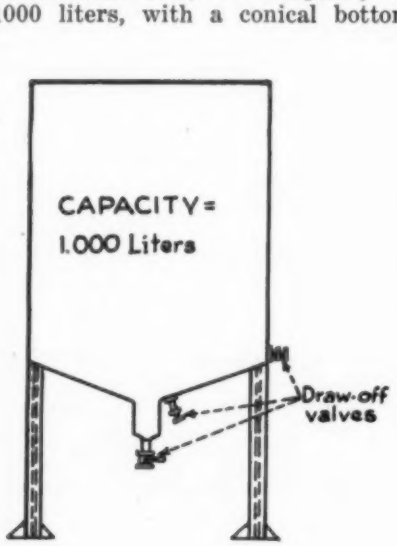
Determinations of the amount of sand in various samples of water have been made by independent observers and they agreed close enough for all practical purposes. There is no difficulty in determining whether the sand in a two (2) liter sample is more or less than one (1) part per million by volume.

During the past two years about

The Author

4500 daily routine determinations of sand in the water pumped from 16 deep wells of the Maracaibo water works have been made and reported weekly. Following the removal of sand that accumulated in the bottom of the wells, during several months of pumping, tests have been made on the water pumped to waste to determine when the sand content decreased to 5 p.p.m. before the water was allowed to enter the collecting system. A routine determination is made of the amount of sand in all samples of water from deep wells that are delivered to the laboratory of the Ministry for physical-chemical analysis.

For the more accurate determination of the amount of sand a cylindrical steel tank, of a capacity of 1000 liters, with a conical bottom may be used. Valved outlets, as shown in the illustration, should be provided. The bottom of the tank should be elevated above the ground by legs attached to it or by an independent frame of steel angles so that a small pail or other receptacle may be placed under the lowest outlet.



TANK
FOR DETERMINATION OF SAND

The tank is filled with the water that is being pumped from the well and is allowed to settle for 30 minutes or longer, if the sand is very fine. The upper outlet is then opened to draw the water down to the cone-shaped bottom. The remaining water is then stirred with a rotary motion to move most of the sand into the small cylinder on the bottom of the tank. The water in the cone above the cylinder is then drawn off slowly through the outlet that is provided. A suitable receptacle, preferably white enameled, is then placed under the cylinder and the lowest outlet opened to discharge the water and sand. The bottom of the tank should be flushed with small amounts of water to remove any grains of sand that may remain.

After the sand has settled to the bottom of the receptacle most of the water may be siphoned off and the sand washed into an Imhoff cone of 1.0 liter capacity, graduated from 0 to 1.0 ml. in 0.1 ml. divisions. A cone with a sharp tip is preferable as more accurate readings of volumes less than 1.0 ml. may be obtained. The volume of sand should be read while it is submerged in water, in order to obtain the true volume, and then converted into equivalent parts per million by volume.

It is preferable to employ a tank with a capacity of 1000 liters, not only to obtain a satisfactory amount of sand but also a direct reading from the Imhoff cone as 1.0 ml. of sand equals 1.0 part per million by volume. The interior of the tank should be kept well painted to prevent the addition of particles of rust to the sand and it should be thoroughly cleaned before a test is made.

The Minister of Public Works is Dr. Manuel Silveira and the Director of the Department of Hydraulic and Sanitary Works is Dr. Carlos Pena Uslar.

*Honorary Member A.W.W.A.

THEORY AND PRACTICE OF SEWAGE SLUDGE DIGESTION TANK HEATING

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The Author

Before entering the field of design and consultation the author gained valuable experience as a plant operator and superintendent. Since the preparation of this article he has been commissioned Captain of U. S. Engineers.

THE artificial maintenance of optimum temperatures in sludge digestion tanks has become standard practice in sewage treatment plant design and operation in the northern portion of the United States, and in other localities subject to adverse climatic conditions. Experience has shown that the lowering of the temperature of digesting sludge in unheated or improperly heated digestion tanks during the winter months seriously reduces biological activity, thus contributing greatly to the operating problems inherent in sewage sludge digestion.

Most engineers and sewage treatment plant operators have reached the conclusion that digestion tank temperatures of from 80° F. to 90° F. are most satisfactory, both as to results obtained, and as to economy of heating and heat exchange. Some plants keep the temperature of digesting sludge well above 90° F., but this practice is the exception rather than the rule. The writer's experience with temperatures at or about 85° F. has, on the whole, been very satisfactory, and there seems to be a very little justification for maintaining temperatures above this level. On the other hand, as temperatures drop below 80° F., the digestion of sludge is gradually retarded. When the temperature drops below 70° F., active digestion ceases almost completely, and the sludge lies dormant until the proper temperature environment is reestablished. The absence of proper temperature environment in the digestion compartments of Imhoff tanks explains in part some of the difficulties which have always been encountered with these units.

Proper Design Voids Most Operating Problems

The problem of providing heat for sludge digestion purposes is largely one of original design, although it becomes necessary at times to install heating facilities at existing plants. Usually, heat exchange equipment installed after a plant has been placed into operation is more or less a make-shift arrangement, and is not nearly so effective or economical as would be a heating system properly designed and installed at the time the plant was constructed. The responsibility for successful sludge digestion rests primarily with the designing engineer. If he realizes the importance of properly designed sludge heating, future operating troubles due to ineffective sludge digestion will be reduced to a minimum.

The technical solution of sludge digestion tank heating problems involves the same fundamental technique used in the solution of other heating and heat trasmission problems. However, there has been some tendency on the part of sanitary engineers to ignore such fundamentals, and to use instead certain empirical formulae or values for the determination of the over-all heating requirements of sludge digestion tanks. These formulae or values have not been adequately substantiated by scientific study and experimentation for all of the varying types of construction and conditions met with in ordinary practice, and the indiscriminate use of such methods has naturally resulted in some plant installations which have been deficient in heating capacity or heat exchange, or which have been over-designed.

However, the careful designer will treat each heating application as an individual problem, involving a consideration of climate, digestion tank construction and exposure, all heat losses through the structure, fresh sludge quantities, and proper type of heat exchange equipment. When broken down into its component parts, the solution of such a problem becomes quite simple, involving only a rudimentary knowledge of the fundamentals of heat transmission.

This discussion will present the subject matter in the same order as would ordinarily be used in the solution of a practical problem in sludge digestion tank heating. Fundamental theory and illustrative problems will be given concurrently for each of the major considerations involved. These are:

1. Heat losses from a sludge digestion tank, involving the determination of heat losses from a heated liquid sludge mass to air or ground through the exposed structural components of the tank.
2. Heat required to raise the temperature of the additions of fresh sludge to the temperature of digesting sludge in a sludge digestion tank.
3. A consideration of methods for applying heat to the contents of a sludge digestion tank.
4. Theory of heat transmission as applied to heat exchangers, and design applications.
5. Selection of heating equipment.

HEAT LOSSES FROM A SLUDGE DIGESTION TANK

Methods of Heat Transfer

Heat transmission (or heat losses) between the mediums on two sides of a wall, roof, or floor takes place by three methods, namely, radiation, convection, and conduction. These methods of heat transfer may be defined as follows:

Radiation is the transmission of heat through space by wave motion in a manner similar to the travel of light waves.

Convection of heat occurs in fluids (liquids or gases), and is the transfer of heat accomplished by the motion of the fluid from a locality where it receives heat to a locality where it gives up heat. The motion of the fluid is usually the result of differences in density caused by temperature differences. This is called free convection. If the motion is produced by some mechanical means, such as a stirrer, or a circulating pump, it is called forced convection.

Conduction is the transfer of heat from one part of a continuous material to another part of the same material, or from one material to another in physical contact with it, without appreciable movement of the particles of the material.

In most cases the actual transfer of heat is accomplished by more than one of the above defined methods. It is therefore preferable to use other terms, such as "transfer," or "transmission," or "conductance," to describe an over-all heat transfer process, reserving the use of the terms "radiation," "convection," and "conduction" for that fraction of the total heat transfer accomplished by the mechanism designated.

For example, consider a wall constructed of one thickness of concrete, an air space, and a second thickness of brick masonry with air on both sides of the composite wall, and with the concrete being adjacent to the warmer air. Heat will be received by the concrete surface from the inside air by radiation, convection and conduction. It will be carried through the homogeneous concrete section by conduction, and carried across to the opposite brick wall surface through the air space by radiation, convection and conduction. From here it will be carried by conduction through the homogeneous brick section to the outer surface of the wall, and will leave this surface by radiation, conduction and convection.

Any digestion tank wall, roof, floating cover, gas dome or bottom floor may be divided into internal and external surfaces, homogeneous materials, and interior air or gas spaces, as the case may be. Practical heat transmission coefficients have been

determined experimentally which will give the total heat transferred through any of these component parts of a structure, and if the method of applying these individual coefficients is thoroughly understood, it is a simple matter to calculate the over-all heat transmission or heat losses through any combination of materials.

Notation Used in Heat Loss Formulae

k = Thermal conductivity of a homogeneous material 1-inch thick, in B.t.u./hr./sq. ft./1° F. difference in temperature between the two surfaces of the material.

f = Film or surface conductance; the amount of heat expressed in B.t.u./hr./sq. ft./1° F. temperature difference transmitted by convection or conduction from a fluid to a surface with which it is in contact, or vice versa, from a surface to the fluid surrounding it.
f_i = coefficient of heat transfer *to* the inner or warm surface
f_o = coefficient of heat transfer *from* the outer or cold surface.

a = Thermal conductance of an air or gas space in B.t.u./hr./sq. ft./1° F. temperature difference.

U = Thermal conductance or over-all coefficient of heat transmission; the amount of heat transmitted in B.t.u./hr./sq. ft./1° F. difference in temperature between the warm and cold sides of a wall, roof or floor.

H = Total heat loss in B.t.u./hr. transmitted through any material, or any combination of materials, such as a wall, roof, cover, or floor of a sludge digestion tank for the total area involved.

A = Area of a surface in square feet as actually measured from the plans or from the structure. Use the net inside or heated dimensions.

T_i = Temperature in °F. of the medium adjacent to the inside or warmer surface; the inside temperature.

T_o = Temperature in °F. of the medium adjacent to the outside or colder surface; the outside temperature.

b = Thickness in inches of homogeneous materials.

Heat Flow by Conduction

The flow of heat through a homogeneous material by conduction is proportional to

(a) the thermal conductivity of the material.
(b) the difference in temperature between the two surfaces or planes considered.
(c) the area through which the heat flows.
and (d) inversely proportional to the distance between the two surfaces or planes considered.

Thus, the total heat transferred between two surfaces of a homogeneous material by conduction can be expressed by the following formula:

$$H = \frac{A\,k\,(T_i - T_o)}{b} \qquad \text{(1)}$$

The coefficients of thermal conductivity given below in Table 1 for homogeneous materials are average values, and have been shown by numerous experiments to be accurate for the typical materials described. Since the conductivity of a material has been found to depend upon its composition, texture and density, these coefficients should not be used for other variations of these materials. Other coefficients can be found in standard reference works.

TABLE 1.

THERMAL CONDUCTIVITY COEFFICIENTS "K"

For Homogeneous Materials (1" Thick) in B.t.u./hr./sq. ft./°F.

Material	k
Cement mortar	12.00
Brickwork, low density	5.00
Brickwork, high density	9.20
Concrete, typical stone structural	12.00
Stone masonry	12.50
Wood, average value for ordinary woods	1.00
Asphalt or tar composition roofing	6.50*
Wrought iron	370.
Steel (1% C)	314.
Pure copper	2640.
Water	4.10

*For thickness used on typical roof construction, *not* per 1-inch of thickness.

Film Conductance

When gaseous fluids such as air or sewage gas are in contact with solids, heat will flow from the warmer to the colder material. The method of heat transfer is principally a combination of convection and conduction. However, the condition of the air or gas has a very important influence on the rate and mode of heat transfer. It is certain that in all cases a stationary film of

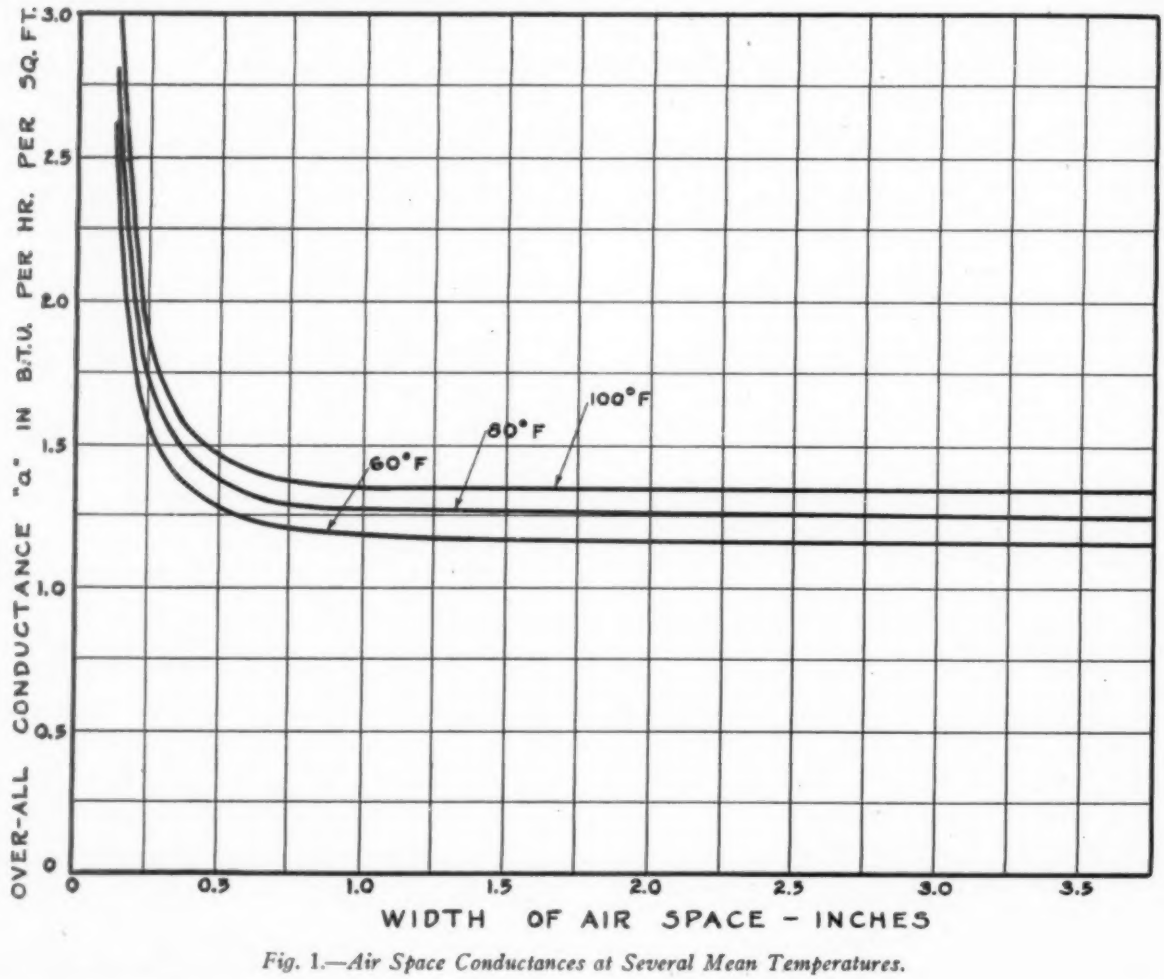

Fig. 1.—Air Space Conductances at Several Mean Temperatures.

air or gas is present on the surface of the solid material, separating the solid from the main body of air or gas. The thickness of this film depends upon its temperature, and upon the velocity of the air or gas parallel to the solid surface.

Therefore, heat transfer through an air or gas film has been found to proceed at a higher rate where movement or velocity exists than is the case for still air. This is illustrated by the film coeficients in common use by engineers for general heating practice. These coefficients are not for convection alone, or for conduction alone, but are experimental, combination over-all film coefficients for heat transfer from a wall surface to or from the main body of adjacent air. They are as follows:

$f_i = 1.65$ B.t.u./hr./sq. ft. for inside air without appreciable motion or velocity.

$f_o = 6.00$ B.t.u./hr./sq. ft. for outside air with a velocity of 15 miles per hour or higher.

The above coefficients are sufficiently accurate for air or gas film conductance as it exists on the inside and exterior surfaces of sludge digestion tank structures, and will be used throughout this discussion. They will be applied to sewage gas (approx. 30 per cent CO_2 and 70 per cent CH_4) as well as to atmospheric air.

Where liquids are in contact with a structure through which heat transmission takes place, film resistance is also present between the surface of the structure and the main body of the liquid. However, as will be explained in some detail later on in connection with the discussion on heat exchangers, the film coefficient is influenced to a large degree by the motion of the liquid. Where temperature differences between liquid and wall surface are small, natural or free convection will be slight, and very little motion of the liquid adjacent to the walls of a digestion tank will be present. Therefore for practical purposes, both the liquid contents of a tank, and the dry or wet earth surrounding the tank, are assumed to be always in direct contact with the structure, without an intermediate film. However, where either dry or wet earth is in contact with the exposed, cold side of the structure, a certain amount of resistance to the transmission of heat is present. While not strictly film resistance, such resistance is of some significance. Therefore, the coefficients for heat transfer from wall surfaces into earth are included in Table 2.

TABLE 2.

FILM COEFFICIENTS "F"
(B.t.u./hr./sq. ft. °F.)

	k
Concrete to or from still air	1.65
Concrete to outside moving air (15 mi. per hr.)	6.00
Brickwork to or from still air	1.65
Brickwork to outside moving air (15 mi. per hr.)	6.00
Steel to or from still air	1.00
Steel to outside moving air (15 mi. per hr.)	3.00
Composition roofing to outside moving air	10.50
Concrete to dry earth	1.00
Concrete to wet earth or to water	2.00

Air and Gas Spaces

Heat is carried across an air or gas space by a combination of radiation, convection or conduction. A large part of the heat transferred across an air space bounded by ordinary building materials such as wood, plaster, concrete, etc., is by radiation. The effect of heat radiation can be greatly reduced by facing the air spaces with metallic surfaces such as aluminum foil, coated sheet steel, or other low-emissitivity, infra-red reflective metal surfaces, thus causing a major portion of the heat to be transmitted by convection. In sludge digestion tank construction, only ordinary building materials are customarily used, and we are therefore concerned only with air spaces bounded by such materials, without reflective surfaces.

It has been found as the result of experiments conducted at the University of Minnesota under a cooperative research agreement with the American Society of Heating and Ventilating Engineers that the over-all thermal conductances across air spaces between ordinary building materials are fairly uniform at a given mean temperature for widths of air space in excess of ¾-inch. This is illustrated by Figure 1, in which curves for several mean temperatures show the relationship between widths of vertical air spaces and over-all surface to surface conductances. From these curves, an average conductance value of 1.25 B.t.u/hr./sq. ft./1° F. temperature difference is established for vertical air spaces ¾-inch or more in width, and for the temperatures ordinarily encountered in sewage sludge digestion practice. When air spaces are not faced with reflective insulating materials, the difference between upward heat flow through single horizontal or sloping air spaces and through single vertical air spaces is comparatively small for the same temperature difference. Therefore, the same conductance value of 1.25 will be used for all air and gas spaces found in sludge digestion tank construction, whether they be vertical or horizontal.

Resistance Concept

It is obvious from the above discussion of heat transmission that the higher the thermal conductivity or over-all conductance of a material or combination of materials, the lower is its resistance to the flow of heat. Thus, the resistance to the flow of heat is inversely proportional to the thermal conductivity or conductance. If R is used to designate over-all resistance, and r_1, r_2, etc., are used to designate unit resistances, then the over-all resistance to the flow of heat through a structure will be

$$R = r_1 + r_2 + \ldots\ldots + r_n \quad \ldots\ldots (2)$$

If Equation (2) is applied to a wall built up of a single homogeneous material b inches thick, then

$$\frac{1}{U} = \frac{1}{f_i} + \frac{b}{k} + \frac{1}{f_o} \quad \ldots\ldots (3)$$

where $\frac{1}{U} = R =$ over-all resistance.

$\frac{1}{f_i} = r_1 =$ inside film resistance.

$\frac{1}{f_o} = r_n =$ outside film resistance.

$\frac{b}{k} = r_2 =$ internal resistance to heat transfer by conduction

For a compound wall built up of two homogeneous materials having thicknesses b_1-inches and b_2-inches, and conductivity coefficients k_1 and k_2 respectively, separated to form an air space of conductance a, and with both sides of the wall exposed to air, the over-all resistance will be

$$\frac{1}{U} = \frac{1}{f_i} + \frac{b_1}{k_1} + \frac{1}{a} + \frac{b_2}{k_2} + \frac{1}{f_o} \quad \ldots\ldots (4)$$

where $\frac{1}{a}$ = air or gas space resistance. The over-all coefficient of heat transmission U then becomes

$$U = \frac{1}{\frac{1}{f_i} + \frac{b_1}{k_1} + \frac{1}{a} + \frac{b_2}{k_2} + \frac{1}{f_o}} \quad \ldots\ldots (5)$$

If the inside air is replaced with water then $\frac{1}{f_i}$ in Equations (4) and (5) becomes zero.

Heat Loss Formulae

Referring back to Equation (1), the same relation exists for a compound wall as is the case for a single homogeneous material. Therefore, the total heat loss between two surfaces of any structure can be expressed by

$$H = A\ U\ (T_1 - T_o) \quad \ldots\ldots (6)$$

If the proper value for U is substituted in Equation (6), as for example the U in Equation (5), then the total heat loss H becomes.

$$H = \frac{A\ (T_1 - T_o)}{\frac{1}{f_i} + \frac{b_1}{k_1} + \frac{1}{a} + \frac{b_2}{k_2} + \frac{1}{f_o}} \quad \ldots\ldots (7)$$

Equation (7) is the fundamental formula for the total heat loss through any material or combination of materials. In applying this formula, it should be remembered that each material in a compound wall, roof, or floor will have a different coefficient k, and that there will be as many values of $\frac{b}{K}$ as there are different materials.

Computation of Sludge Digestion Tank Heat Losses

The following problem will illustrate how the fundamental formulae and heat flow coefficients may be applied to the determination of heat losses from sludge digestion tanks. A common type of construction will be shown, and the method used in solving this problem can be extended to almost any type of digestion tank design. Since all such calculations are at the best only approximate, the slide rule will be used throughout.

Illustrative Problem 1.

Calculate the total heat loss, in B.t.u. per hour, for the sludge digestion tank shown in Figure 2. The inside sludge temperature will be 85° F.; the minimum sustained winter air temperature is estimated at 15° F.; the minimum sustained dry earth temperature at 40° F.; and the minimum sustained wet earth temperature at 50° F. For the purpose of this computation, heat losses from the scum-covered annular ring of water surface between the floating cover and the tank walls will be ignored, as this loss will be very small, and will be more than compensated for by

assuming the diameter of the floating cover to be equal to the inside diameter of the tank.

The total heat loss will be the sum of the individual losses through the tank floor, the several vertical sections of the wall, and the floating cover. As stated above, where inside water or sludge is in direct contact with the structure, the resistance $\frac{1}{f_i}$ will be zero.

Solution

1. Heat loss H_1 through the tank floor. This involves only the heat transfer through the 9-inch thick concrete slab, and from the bottom of the slab into the wet earth.

$$H_1 = \frac{A\ (T_i - T_o)}{\frac{1}{f_i} + \frac{b}{k} + \frac{1}{f_o}}$$

$$= \frac{1290\text{ sq. ft. } (85 - 50)}{0 + \frac{9}{12.00} + \frac{1}{2.00}}$$

$$= 36{,}200\text{ B.t.u./hr.}$$

2. Heat loss H_2 through portion of wall below ground water table. This calculation is similar to that for H_1.

$$H_2 = \frac{1260\text{ sq. ft. } (85 - 50)}{0 + \frac{12}{12.00} + \frac{1}{2.00}}$$

$$= 29{,}400\text{ B.t.u./hr.}$$

3. Heat loss H_3 through portion of wall between ground water table and ground surface. This calculation is similar to that for H_4, except that heat is transferred into dry earth instead of into wet earth.

$$H_3 = \frac{755\text{ sq. ft. } (85 - 40)}{0 + \frac{12}{12.00} + \frac{1}{1.00}}$$

$$= 17{,}000\text{ B.t.u./hr.}$$

4. Heat loss H_4 through portion of wall exposed to outside air. This calculation involves the use of the common film coefficient from concrete to outside air. Otherwise, the method is the same as for H_3.

$$H_4 = \frac{502\text{ sq. ft. } (85 - 15)}{0 + \frac{12}{12.00} + \frac{1}{6.00}}$$

$$= 30{,}000\text{ B.t.u./hr.}$$

5. Heat loss H_5 through gas dome. This calculation involves the transfer of heat across the gas space, through the inside gas film, through the very high conductance of the steel plate and through the outside air film. It is evident that the resistance to the transfer of heat which is offered by the steel plate could be ignored without affecting the slide-rule result.

$$H_5 = \frac{A\ (T_i - T_o)}{\frac{1}{a} + \frac{1}{f_i} + \frac{b}{k} + \frac{1}{f_o}}$$

$$= \frac{10\text{ sq. ft. } (85 - 15)}{\frac{1}{1.25} + \frac{1}{1.65} + \frac{0.25}{314} + \frac{1}{6.00}}$$

$$= 500\text{ B.t.u./hr.}$$

6. Heat loss H_6 through floating cover, diameter taken as 40 feet. Four layers of material are involved, namely, steel, air, wood deck, and composition roofing.

$$H_6 = \frac{A\ (T_i - T_o)}{\frac{1}{f_i} + \frac{b_1}{k_1} + \frac{1}{a} + \frac{b_2}{k_2} + \frac{b_3}{k_3} + \frac{1}{f_o}}$$

$$= \frac{(1260 - 10)\text{ sq. ft. } \times\ (85 - 15)}{0 + \frac{0.25}{314} + \frac{1}{1.25} + \frac{0.875}{1.00} + \frac{1}{6.50} + \frac{1}{6.00}}$$

$$= 43{,}800\text{ B.t.u./hr.}$$

7. The total heat loss becomes—

$$H_t = H_1 + H_2 + H_3 + H_4 + H_5 + H_6$$

$$= 156{,}900\text{ B.t.u./hr.}$$

HEAT REQUIRED BY FRESH SLUDGE ADDITIONS

Method

The heat required to raise the temperature of the fresh sludge additions to the temperature of the mass of digesting sludge in the tank is obtained by a simple calculation. For practical pur-

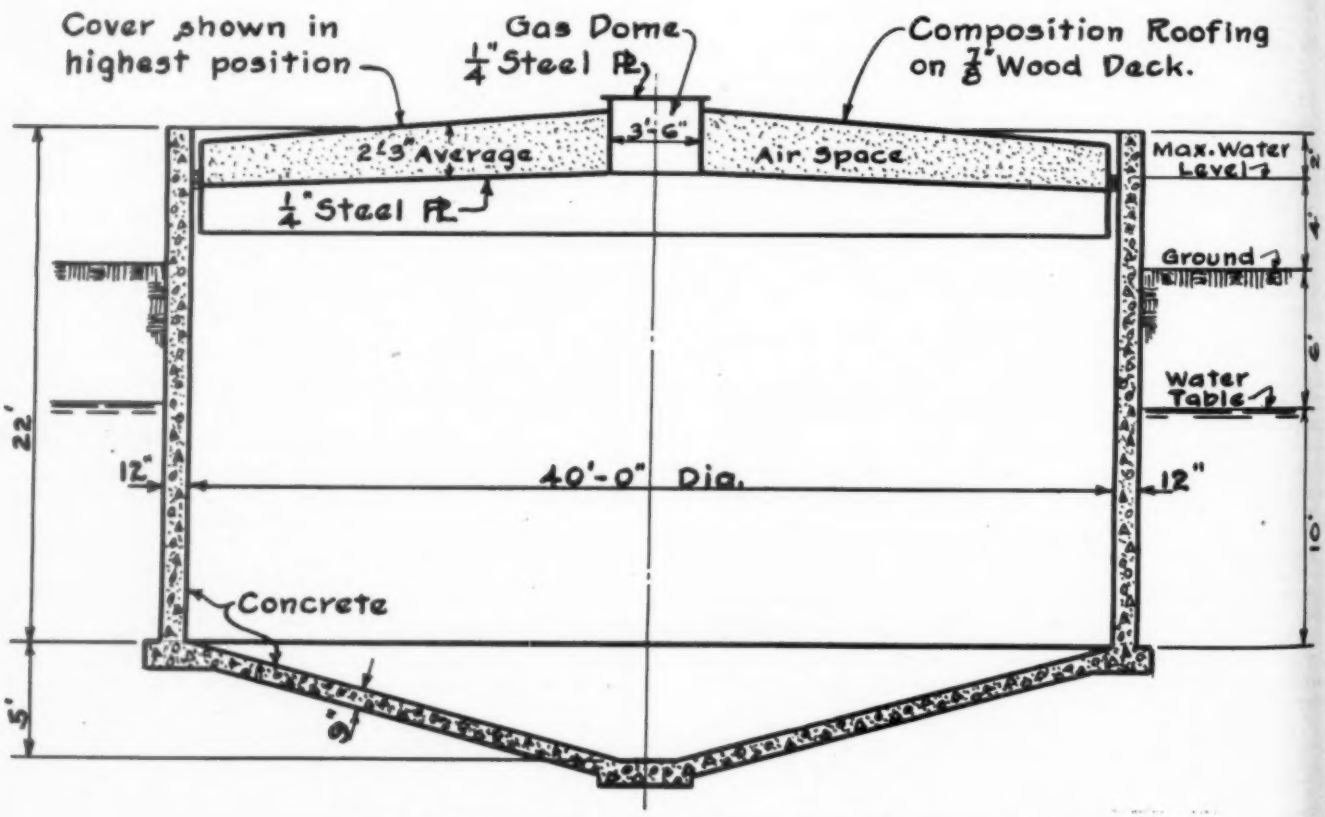

Fig. 2.—Typical Sludge Digestion Tank with Floating Cover

poses, one B.t.u. is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. Sludge has approximately the same characteristics as has water. Therefore the

$$\text{Heat required} = \frac{W\ (T_s - T_1)}{24} = \text{B.t.u./hr.} \quad \ldots\ldots\ldots\ldots\ (8)$$

where

W = Weight in pounds per day of fresh sludge additions.
T_s = Temperature in °F. of fresh sludge, ordinarily the same as the sewage flowing through the plant.
T_1 = Temperature in °F. of the digesting sludge in the digestion tank.

Quantity of Fresh Sludge Additions

A sewage treatment plant which has been in operation for some time should have available a back-log of operating records which will indicate the average daily volume of liquid sludge additions to the digestion system. Wherever possible, such records should be utilized in the calculation of digestion tank heating requirements. Where such records are not available, or in the case of a new plant design, the engineer must carefully estimate the probable quantities of fresh sludge to be expected, basing the estimate on his own experience, or on the experience of others.

The quantity of fresh sludge added to a sludge digestion tank is influenced by the character of the sewage, the type of sewage treatment process, the method of plant operation, and also to a large extent by the degree of care exercised by the plant operators in limiting fresh sludge pumpings to the thicker, more concentrated liquid. Obviously, the addition of large quantities of excess water to the sludge digestion tank may not only overtax the heating facilities, but may also seriously interfere with the normal functioning of the sludge digestion processes.

The average daily quantities of fresh sludge solids to be expected at different types of sewage treatment plants are shown in Table 3. These quantities are for domestic sewage, without an appreciable proportion of industrial wastes, and without storm water drainage. In using these average figures for design, some allowance should be made for higher-than-average rates which may be sustained over periods of time long enough to influence over-all heat requirements. The writer believes that an increase of 20 per cent above these values provides a safe allowance for all practical purposes, unless more definite information is available.

TABLE 3.

AVERAGE DAILY QUANTITIES OF FRESH LIQUID SOLIDS ADDED TO SLUDGE DIGESTION TANKS

	Average Moisture %	Sludge to Digester, cu. ft./day/capita High	Aver.	Low
Primary Treatment Plants	95	.070	.050	.035
Chemical Precipitation Plants..	92.5	.125	.085	.070
Trickling Filter Plants*.....	94	.080	.060	.045
Activated Sludge Plants.....	98.5	.280	.150	.100

*Including Humus Tanks.

Illustrative Problem 2.

Calculate the heat required by the fresh sludge additions to the sludge digestion tank shown in Problem 1. This tank forms part of a primary sewage treatment plant, and is designed for 16,000 persons at 3 cu. ft. per capita. The minimum sustained fresh sludge temperature T_s is expected to be 45° F. From Problem 1, $T_1 = 85°$ F.

Solution

The average daily quantity of fresh sludge additions is estimated from Table 3 at .050 cu. ft./day.

$$W = .050 \times 16{,}000 \times 62.5 \times 1.20\% = 60{,}000 \text{ lbs./day}$$

$$\text{In Equation (8), heat required} = \frac{60{,}000\ (85 - 45)}{24}$$

$$= 100{,}000 \text{ B.t.u./hr.}$$

Total Heat Required

It can be seen by the foregoing discussion that the total heat required for a sludge digestion tank is the sum of heat required to compensate for the heat losses from the liquid through the walls, roof and floor of the tank, and the heat required to raise the temperature of the incoming fresh sludge to the temperature of the digesting sludge. Thus, for the digestion tank of Problems 1 and 2, the total heat required will be

Heat loss through structure..	= 156,900 B.t.u./hr.
Heat required for fresh sludge	= 100,000 B.t.u./hr.
Total heat required	256,900 B.t.u./hr.

METHODS FOR HEATING SLUDGE DIGESTION TANKS

Having determined the total heat requirements for a sludge digestion tank, the final element which enters into the thermal design of its heating system is the selection and calculation of an adequate heat exchange system. Several methods may be used for transferring heat into the liquid contents of a tank. However, some methods, such as the use of steam or hot air in heating coils, are inapplicable to this type of problem since the resulting high temperature of the heat exchangers would be too conducive to scale formation. The methods worthy of our consideration are as follows:

1. Circulation of hot water through horizontal pipes placed around the inside periphery of a tank.
2. Circulation of hot water through vertical banks of heating pipes suspended in the liquid.
3. Direct introduction of hot water.
4. Preheating the fresh sludge before it is added to a tank.

Circulation of Hot Water Through Horizontal Pipes. This is the most common method of transferring heat into a sludge digestion tank. The usual arrangement is to install the heating piping in the form of a spiral coil around the inside periphery of the tank as shown by Figure 3.

The spacing of the successive turns of the coil is usually about 12 inches. Hot water is admitted to the top of the coil and the colder return water is taken away from the lowest point.

In some instances, heating coils have been placed at or very near the floor of the tank. This practice is not too good because it tends to keep the more thoroughly digested sludge at a high temperature while the actively digesting sludge higher up in the tank receives only the benefit of somewhat lower temperatures. The most favorable location for the heating coil seems to be from a level about 6 ft. above the floor to a level not above the middle of the tank. This range usually covers the region of active sludge digestion.

Circulation of Hot Water Through Vertical Banks of Pipes.—Another common type of heat exchanger for digestion tanks with fixed roofs or covers is the vertical, multiple-bank type suspended from the roof. This type of heat exchanger is, or should be, removable from above. The vertical pipes are in series and are placed very close together, from 5 to 7 inches on centers. This type of heat exchanger is illustrated in Figure 4.

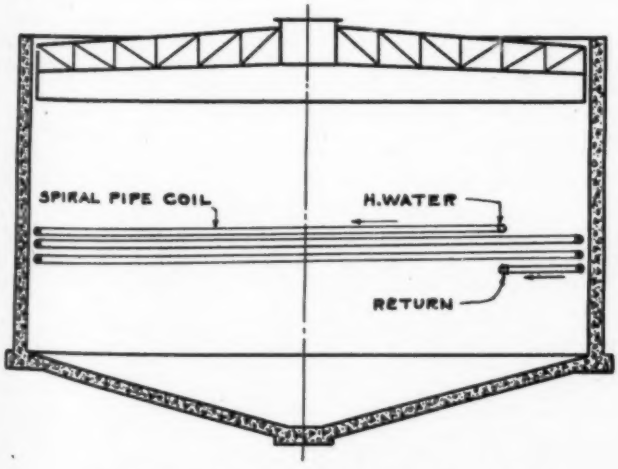

Fig. 3.—Digestion Tank with Spiral Pipe Coil

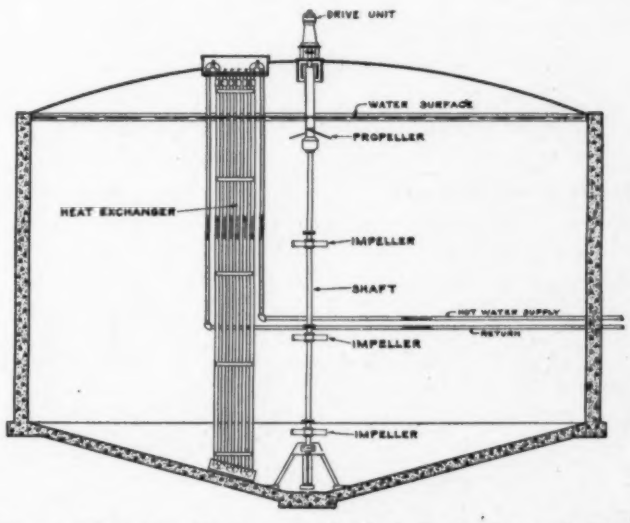

Fig. 4.—Digestion Tank with Vertical Bank Type of Heat Exchanger

The hot water supply is introduced into the top of the first pipe, and is forced down and up through succeeding pipes until it is removed from the top of the last pipe. Such a unit should be located at or near the center of a small tank; while several units, distributed uniformly, should be used in larger tanks.

Direct Introduction of Hot Water.—The practice of introducing hot water directly into a digestion tank is of German origin, and up-to-date has not found much favor in this country. Several installations have been reported, but not much data as to their efficiency is available.

Keefer[1] found at Baltimore in comparative plant-scale tests that more heat was required to heat the sludge by the direct addition of hot water than was the case with well designed heat exchangers using circulated hot water. He claims, however, that the cost of constructing a pipe coil and return piping to the heating plant is saved; also since water at considerable pressure is generally available, it can be added directly to the tank without the use of pumps, whereas hot water circulating through the pipe coils must be pumped. But it must be remembered that the direct connection of a high pressure water supply, if potable, constitutes a cross-connection which is distinctly contrary to standard sanitary practice and health codes. Furthermore, the actual pumping of circulated water is a minor operation, involving very small pumps and low operating costs.

Downes[2], on the other hand, asserts that the practice of introducing hot water directly into the sludge contents of a digestion tank is detrimental as it tends to segregate grit and coarse particles such as seeds and inorganic materials from the sludge mass, thus accelerating accumulations of such materials in the bottom of the tank.

It is the writer's opinion that the objections to the direct addition of previously heated water more than outweigh the doubtful economy in first cost. Where outside water is used, the cost of purchase is in itself a continuing expense. In addition to the objections cited by Downes, the continuous introduction of hot water into the tank tends to thin out the sludge, thus reducing the amount of space available for digestion purposes. Naturally, there is a concurrent interference with sludge concentration, which is exactly the reverse of the above procedure.

Preheating the Fresh Sludge.—This method has been tried at a few plants. While not much operating data is available, it seems to the writer that the preheating of fresh undigested sludge would introduce an entirely new set of difficulties, not the least of which would be continuous sludge encrustation on the outside or inside of any heat exchanger used. This is due to the fact that the fresh sludge would necessarily have to be heated to a temperature considerably higher than the tank temperatures because it would be necessary to overcome all heat losses from the structure in addition to the mere raising of the fresh sludge to the temperature of the digesting sludge.

(Ed. Note.—Since the author wrote this paper, an article titled "Sludge Digestion Temperature Control With Live Steam," by A. M. Rawn, appeared in the July, 1942, issue of WATER WORKS AND SEWERAGE. Mr. Rawn's article, which describes the use of live steam for direct heating of raw sludge, or to raise digestion tank temperatures by direct application, may also be found in the Reference and Data Section of this issue.)

More experience with this method of heat exchange may ultimately demonstrate its fitness, both as to economy and operating effectiveness.

SLUDGE DIGESTION TANK HEAT EXCHANGERS

The theory involved in heat transfer from hot water circulated through spiral pipe coils around the inside of a digestion tank is quite similar to that involved in heat transfer from hot water circulated through banks of pipes suspended vertically into the liquid contents of a tank. Both types of heat exchangers involve a consideration of fluid motion, and of heat transfer by convection and conduction. As will be shown, the resistance in thin walled pipes and tubing to heat transfer by conduction is often much less than the resistance through the fluid films immediately in contact with the pipe walls. Film resistance is to a large extent influenced by convection, although the actual passage of heat through such a film is principally by conduction.

Consider the case of a fluid in contact with the wall of a pipe whose temperature is lower than that of the fluid, as shown by the left-hand portion of Figure 5. Although the main body of the fluid passing through the pipe may or may not be in turbulent motion, the thin film of fluid in contact with the pipe is relatively stagnant as the result of friction with the wall. The thickness of this stagnant film is not clearly defined and varies as the degree of turbulence of the passing fluid. Sincee the heat is transferred through this film largely by conduction rather than by convection, the entire process by which heat is transferred to the surface of the pipe from the main body of the fluid is somewheat complicated. Calculations are simplified, however, by the use of so-called *convection coefficients* which include the combined effect of both conduction and convection.

For digestion tank heating with pipe heat exchangers, it is assumed that a state of equilibrium has been reached; i. e., the temperature gradient is assumed to remain constant and not change with time, and the rate of heat transfer through the wall of the pipe is assumed equal to the rate at which heat is absorbed by the liquid outside of the pipe. In addition, the effect of radiation is neglected, since the rate of heat transfer by radiation will be negligible compared to the rate of heat transfer by convection.

Film Coefficient.—From the above discussion it can be seen that there is no difference between this over-all film coefficient and the film coefficient f previously defined under "Notation used in heat loss formulae." It can be conveniently re-defined as the rate of heat transfer by convection between the inner or outer surface of a pipe wall and the main body of the adjacent fluid, in B.t.u./hr./sq. ft.°/F. temperature difference. Thus,

$$H_c = A\, f\, (\Delta T) \qquad (9)$$

where H_c = rate of heat transfer by convection, B.t.u./hr.
f = film coefficient, B.t.u./hr./sq. ft. °F.
A = area of wall surface in sq. ft.
ΔT = temperature difference between the surface of the wall and the main body of the fluid in °F.
ΔT_i = inside temperature difference.
ΔT_o = outside temperature difference.

Factors Affecting the Film Coefficient f.—There are several types of heat transfer by convection. In this study we are

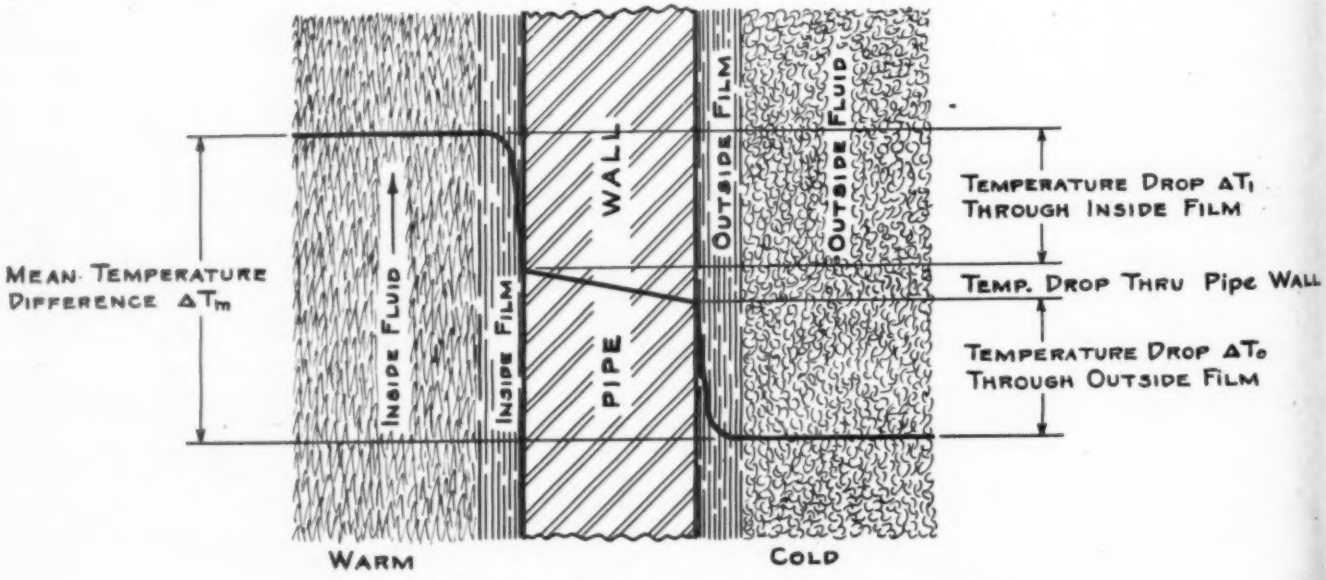

Fig. 5.—Temperature gradient, Fluid to Fluid, Through a Pipe Wall

concerned only with the type in which the fluid does not change phase, i. e., the fluid remains either a liquid or a gas during the process. In this type of heat transfer, the film coefficient depends upon the turbulence of the fluid, increasing as the turbulence increases. The film coefficient also depends upon whether a fluid is being heated or cooled. The difference in the film coefficients for heating and cooling decreases as the turbulence of the fluid increases.

In addition to the various factors already mentioned, the film coefficients are affected by the presence of scale or other deposits on either surface of the pipe wall. Such deposits act as insulation, and may greatly reduce the rate of heat transfer.

Turbulent Flow Inside of a Pipe.—Where a fluid is flowing through a pipe, the film coefficient will increase as the velocity increases. At very low velocities, the flow will be streamline or laminar, and at higher velocities, it is usually turbulent. Also, for natural or free convection, the turbulence and film coefficient increase as the temperature difference ΔT increases.

The critical velocity above which fluid flow in a pipe is turbulent and below which it is streamline can be obtained from:

$$v = \frac{0.58\mu}{D\rho} \qquad (10)$$

Illustrative Problem 3 (*Critical velocity for turbulent flow*)

where v = velocity in ft./sec.
μ = viscosity in lb./ft./hr.
D = inside pipe diameter in feet.
ρ = density in lb./cu. ft.

Calculate the critical velocity for water in a 3-inch inside diameter pipe. The mean temperature of the water is 130° F. From Table 4, the viscosity of this water is 1.31 lb./ft./hr., and the density is 61.58 lb./cu. ft. Then, from Equation (10)

$$v = \frac{0.58 \times 1.31}{.25 \times 61.58}$$

= .049 ft. per sec. critical velocity.

TABLE 4.
Density and Viscosity of Water

Temperature °F.	Density ρ lb./cu. ft.	Viscosity μ lb./ft./hr.
70	62.31	2.42
80	62.21	2.17
90	62.12	1.96
100	62.00	1.75
110	61.87	1.57
120	61.71	1.43
130	61.58	1.31
140	61.42	1.21
150	61.20	1.11
160	61.03	1.01
170	60.78	.92

Forced Convection Outside of a Pipe

Due to the increased velocity of movement of the liquid past a heat exchanger with forced convection produced by mechanical agitation or stirring, the resistance of the film to the transfer of heat is correspondingly decreased. In general, the decrease in resistance, or in other words, the increase in the film coefficient, is proportional to the velocity of motion past the heat exchanger. Where the agitation of the liquid is irregular, it is very difficult to estimate liquid velocities. But where a steady, uniform stirring action is present, the contents of a circular tank assume a definite motion which depends upon the type and speed of the stirring mechanism.

Positive stirring mechanisms usually found in sludge digestion tanks consist of short horizontal blades mounted on a vertical shaft, as illustrated in Figure 6. The speed of rotation is generally about 60 r.p.m.

The entire liquid mass in a circular tank will not rotate with the same rotary speed as that of the stirrer. The greater the distance from the axis of rotation, the slower will be the rotary motion. It has been determined that the liquid speed of rotation very closely varies as the square root of the diameter of the vertical plane of motion. Thus, the velocity of horizontal motion of the liquid at any distance z from the axis of the stirrer will be

$$v = \frac{\pi\sqrt{2z} \times \text{r.p.m. of stirrer}}{60} \qquad (11)$$

where v = Velocity in ft./sec.
z = Distance in feet from stirrer to vertical plane of liquid motion.

The action of this type of stirring is clearly shown by Figure 6.

Mean Temperature Difference ΔT_m.—The temperature difference between the hot water inside a heating pipe and the cooler water in the digestion tank does not remain constant throughout the length of the heat exchanger. The temperature difference between the two fluids is greatest at the point where the pipe first enters the tank liquid, and smallest where it leaves. A more exact *mean temperature difference* is a logarithmic function of the two terminal temperature differences. However, for ordinary sludge digestion practice, the arithmetic mean of the terminal temperature difference can be used instead of the logarithmic mean without introducing an error in this value of more than 3 per cent.

Illustrative Problem 4 (*Mean Temperature Difference*)

The average temperature of the liquid in a sludge digestion tank is 85° F. The temperature of the hot water supply to the circular pipe coil is 135° F., and of the return 120° F. Determine the mean temperature difference.

$$\Delta T_m = \frac{(135 - 85) + (120 - 85)}{2}$$

$$= 42.5°\text{F.}$$

Determination of Film Coefficients

In the design of sludge digestion tank heat exchangers, we may be concerned with five different types of convection for which film coefficients must be determined, namely

Case 1. Water cooled inside of horizontal or vertical pipes, turbulent flow.

Case 2. Water heated outside of single horizontal pipes, forced convection.

Case 3. Water heated outside of single horizontal pipes, free convection.

Case 4. Water heated outside of vertical banks of piping, free convection.

Case 5. Water heated outside of vertical banks of piping, forced convection.

The same method is used in each case for the determination of the film coefficient. Charts have been prepared which show for each case an arbitrary or assumed coefficient f_b called the "base coefficient." Correction factors are then given for changing these values of f_b to conditions of temperature and pipe diameter other than those assumed for the charts. The general equation for the film coefficient is

$$f_i \text{ or } f_o = f_b \times F_t \times F_d \qquad (12)$$

Where f_i = inside film coefficient, B.t.u./hr./sq. ft./°F.
f_o = outside film coefficient, B.t.u./hr./sq. ft./°F.
f_b = film coefficient, "base" conditions, B.t.u./hr./sq. ft./°F.
F_t = temperature correction factor corresponding to the mean temperature T_m of the main body of the water.
F_d = pipe diameter correction factor corresponding to the pipe diameter.

Case 1. Water Cooled Inside of Horizontal or Vertical Pipes Turbulent Flow.—The film coefficient f_i can be determined from the following equation:

$$f_i = f_b \times F_t \times F_d$$

Where f_b = base value of film coefficient, from Fig. 7.
F_t = temperature—correction factor, from Table 5.
F_d = diameter—correction factor for inside diameter of pipe, from Table 6.

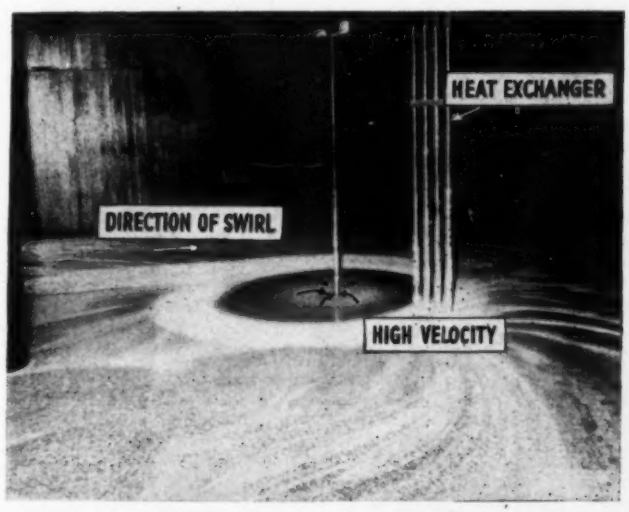

Fig. 6—Vertical Stirring in a Sludge Digestion Tank
(By courtesy of The Dorr Company)

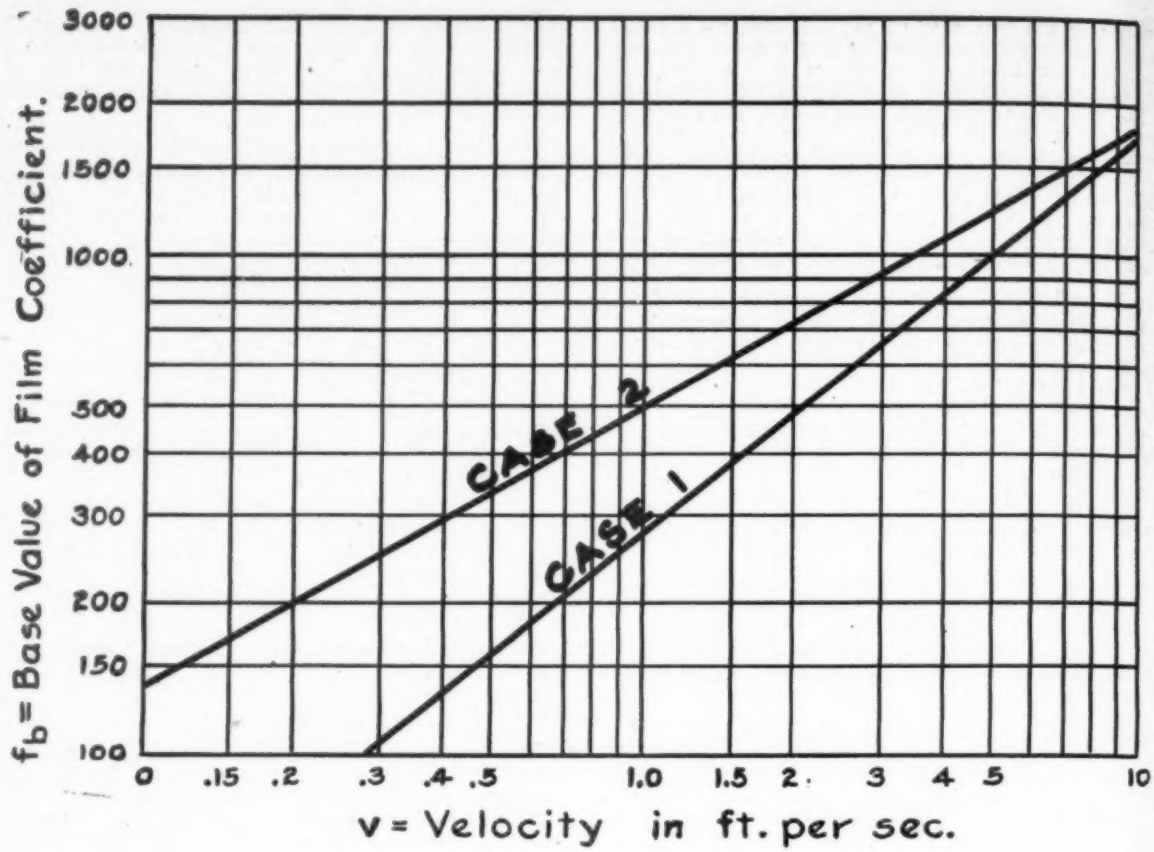

Fig. 7.—Base Values of Coefficient f_b for Case 1 and Case 2

TABLE 5.

Temperature Correction Factor for Water—Case 1

Aver. Temp.	F_t
50°F.	0.66
100°F.	1.00
150°F.	1.30
200°F.	1.56

TABLE 6.

Diameter Correction Factor for Case 1

Inside Pipe Dia. Inches	F_t	Inside Pipe Dia. Inches	F_d
0.20	1.38	1.20	0.97
0.30	1.27	1.30	0.95
0.40	1.20	1.40	0.94
0.50	1.15	1.50	0.92
0.60	1.11	....	....
0.70	1.08	2.00	0.87
0.80	1.05	2.50	0.83
0.90	1.02	3.00	0.80
1.00	1.00	3.50	0.78
1.10	0.98	4.00	0.76

Case 2. Water Heated Outside of Single Horizontal Pipes, Forced Convection.—As previously stated, this type of convection differs from free convection by reason of the artificial movement of the liquid past the pipe caused by mechanical agitation such as stirrers. As in Case 1, the film coefficient f_o can be determined from

$$f_o = f_b \times F_t \times F_d$$

Where f_b = base value of film coefficient, from Fig. 7.
F_t = temperature—correction factor, from Table 7.
F_d = diameter—correction factor for inside diameter of pipe, from Table 6.

TABLE 7.

Temperature Correction Factor for Water—Case 2

Aver. Temp.	F_t
50°F.	0.77
100°F.	1.00
150°F.	1.16
200°F.	1.30

TABLE 8.

Diameter Correction Factor for Case 2

Nominal Pipe Dia. Inches	External Pipe Dia. Inches	F_d
.75	1.050	.98
1.00	1.315	.90
1.25	1.660	.81
1.50	1.900	.75
2.00	2.375	.68
2.50	2.875	.63
3.00	3.500	.58
3.50	4.000	.54
4.00	4.500	.50

Case 3. Water Heated Outside of Single Horizontal Pipes, Free Convection.—In this case the base value of the film coefficient is obtained from Fig. 8 as a function of ΔT_o in °F., in which ΔT_o is the temperature difference between the main body of fluid and the pipe wall. It is sufficiently accurate to take ΔT_o as $\frac{1}{2}\Delta T_m$

$$f_o = f_b \times F_t \times F_d$$

Where f_b = base value of film coefficient, from Fig. 8.
F_t = temperature—correction factor, from Table 9.
F_d = diameter—correction factor for outside pipe diameter, from Table 10.

TABLE 9.

Temperature Correction Factor for Water—Case 3

Aver. Temp.	F_t
50°F.	0.77
100°F.	1.00
150°F.	1.15
200°	1.26

TABLE 10.

Diameter Correction Factor for Case 3

Nominal Pipe Dia. Inches	External Pipe Dia. Inches	F_d
.75	1.050	.98
1.00	1.315	.93
1.25	1.660	.88
1.50	1.900	.85
2.00	2.375	.81
2.50	2.875	.77
3.00	3.50	.73
3.50	4.00	.71
4.00	4.50	.69

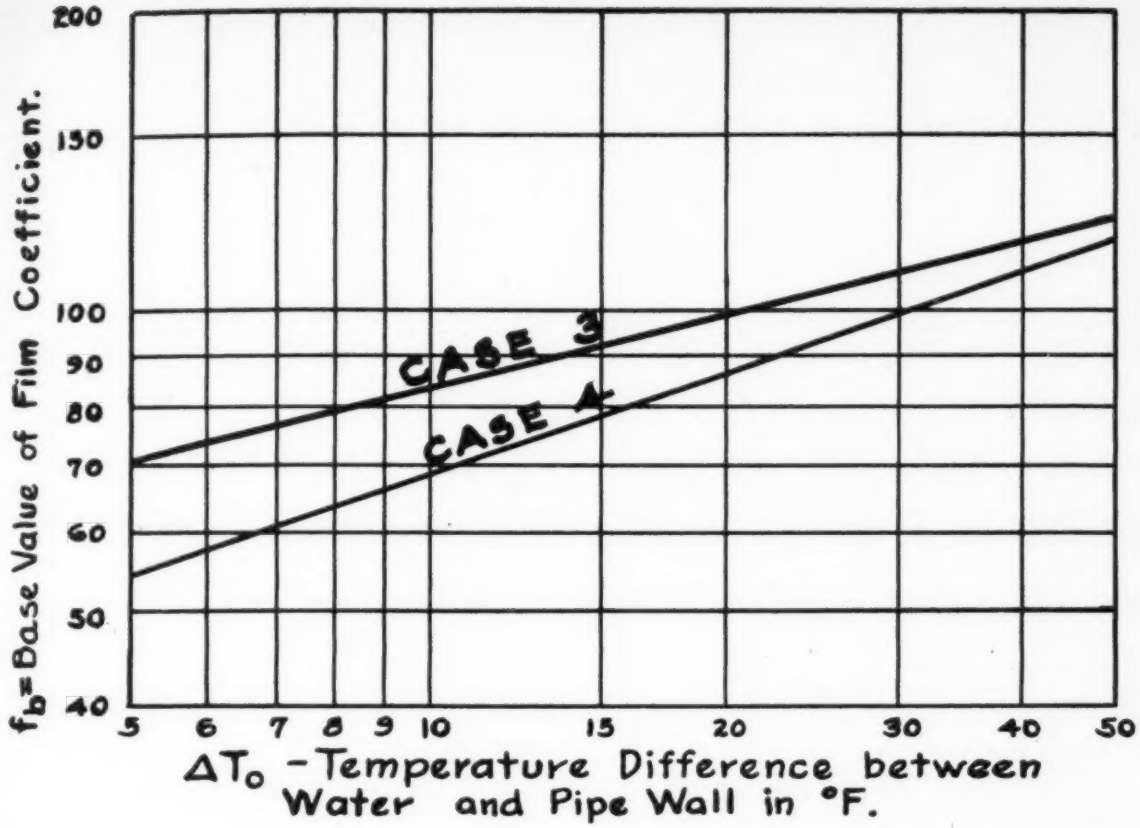

Fig. 8.—Base Values of Coefficient f_b for Cases 3 and 4.

Case 4. Water Heated Outside of Vertical Banks of Piping, Free Convection.—The method for determining the film coefficient in this case is similar to that given for Case 3, except that no diameter—correction factor is necessary. Thus

$$f_o = f_b \times F_t$$

Where f_b = base value of film coefficient, from Fig. 8.
F_t = temperature—correction factor, from Table 11.

TABLE 11.

Temperature Correction Factor for Water—Case 4

Aver. Temp.	F_t
50°F.	.73
100°F.	1.00
150°F.	1.19
200°F.	1.33

Case 5. Water Heated Outside of Vertical Banks of Piping, Forced Convection.—Approximate values of the film coefficient for water being circulated outside of vertical, parallel-tube heat exchangers by artificial stirring or agitation can be determined as a function of the film coefficients determined for single tubes in Case 2. Thus

$$f_o = 1.2 \times f_{s.t.}$$

in which $f_{s.t.}$ should be evaluated at a velocity as estimated at the narrowest section between the parallel pipes of the unit.

Over-all Heat Transfer.—In the type of heat transfer equipment commonly used in sludge digestion tanks, one fluid receives heat from another fluid, the two fluids being separated by the solid wall of a pipe or tube. When designing such heat exchangers, the temperatures of the fluids inside and outside the pipes are usually known, or are controlling criteria, but the temperature of the pipe wall is not known. Consequently, the expected rate of heat transfer cannot be calculated directly from the film coefficients, since these are based on the temperature difference between the *pipe wall*, and the fluids. However, the expected rate of heat transfer can be readily calculated from the *over-all coefficient U*, because this coefficient is based on the temperature difference between the two fluids. The coefficient U can be defined as the rate of heat transfer from one fluid to another per unit area of the separating wall per degree mean temperature difference between the two fluids. Thus

$$H = AU\ (\Delta T_m) \quad \ldots\ldots\ldots\ldots\ (13)$$

Where H = total heat transfer in B.t.u. per hour.
U = the over-all coefficient, B.t.u./hr./sq. ft./°F.
ΔT_m = the mean temperature difference between the main bodies of the fluids on each side of the separating on pipe wall in °F.

Relation Between Film Coefficients and Over-all Coefficient.—By the resistance concept, the over-all coefficient U can be calculated from the film coefficients and the conductivity coefficient of the pipe wall when these are known. For thin-walled pipes, the area is based upon the outside surface. Thus, for clean pipes,

$$\frac{1}{U} = \frac{1}{f_i} + \frac{b}{k} + \frac{1}{f_o} \quad \ldots\ldots\ldots\ldots\ (14)$$

Where f_i = film coefficient for the inside of the pipe, B.t.u./hr./sq. ft./°F.
f_o = film coefficient for the outside of the pipe, B.t.u./hr./sq. ft./°F.
f = thickness of pipe wall in inches.
k = coefficient of thermal conductivity of the pipe wall, B.t.u./hr./sq. ft./°F./inch of thickness.

Equation (14) is the theoretical formula for the resistance 1/U to the transfer of heat between the two main bodies of fluid. However, when the values of the coefficients f_i, f_o and k are examined, it can be readily seen that the resistance b/k offered by the pipe wall is most often negligible compared to the resistances $1/f_i$ and $1/f_o$. Therefore, for practical purposes, sufficiently accurate values of the over-all coefficient U can be calculated if the resistance through the pipe wall is omitted. Thus

$$\frac{1}{U} = \frac{1}{f_i} + \frac{1}{f_o} \quad \ldots\ldots\ldots\ldots\ (15)$$

and

$$U = \frac{1}{\frac{1}{f_i} + \frac{1}{f_o}} \quad \ldots\ldots\ldots\ldots\ (16)$$

Effect of Scale on Over-all Coefficient U.—Equations (15) and (16) for calculating the over-all coefficient U involve the assumption that both inner and outer surfaces of the pipe are clean and free from scale. Under sludge digestion tank conditions, the outside of the pipe will always have a crust or scale of appreciable thickness, dependent to some extent on the temperature of the water circulated through the pipe. Higher circulating water temperatures are conducive to a greater degree of incrus-

tation on the pipes. Therefore, it is good operating practice to keep the temperature of the hot water supply to the heat exchanger below 150° F.

The inside of a heating pipe will also accumulate some scale. The degree of scale is almost entirely dependent upon the hardness of the water. A hard water is conducive to scale formation while a soft water will be correspondingly free from this trouble.

The following values for dirt and scale coefficients have been taken from the Standards of Heat Exchange Institute[3].

TABLE 12.
Scale Coefficients "S" in B.t.u./hr./sq. ft./°F.
S = Scale Coefficient

Kind of Water	125°F. or less	Over 125°F.
Hard Water (over 15 grains/gal.)	330	200
Lake and Eastern Well Waters	1000	500
River Waters		
Maximum	500	330
Mississippi	330	250
Delaware, Schuylkill	330	250
East River	330	250
Chicago Sanitary Canal	130	100
Sewage Sludge	70	50
Distilled Water	2000	2000

Therefore, if the resistances due to inside and outside scale formations are added to Equations (15) and (16), then for thin-walled pipes

$$\frac{1}{U} = \frac{1}{f_i} + \frac{1}{f_o} + \frac{1}{S_i} + \frac{1}{S_o}$$

$$U = \frac{1}{\frac{1}{f_i} + \frac{1}{f_o} + \frac{1}{S_i} + \frac{1}{S_o}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (17)$$

where S_i = inside scale coefficient, B.t.u./hr./sq. ft./°F.
S_o = outside scale coefficient, B.t.u./hr./sq. ft./°F.

Circulating Water.—The quantity of hot water to be circulated through a heat exchanger depends upon the total heat to be transmitted, and the temperature drop between the hot water supply and return. Obviously, the greater the temperature drop for a given B.t.u. exchange, the lower is the quantity of hot water required, and vice versa. A practical temperature drop is about 20° F., as for example, if the hot water supply is 130° F., the return will be 110° F. Therefore, the quantity of water required is

$$Q = \frac{\text{B.t.u./hr.}}{(T_s - T_r) \times 60 \times 8.33}$$

$$= \frac{\text{B.t.u./hr.}}{(T_s - T_r) \times 500} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (18)$$

where Q = rate of hot water circulation, g.p.m.
T_s = temperature of hot water supply, °F.
T_r = temperature of hot water return, °F.

Illustrative Problem 5 (*Design of Heat Exchanger—Horizontal Heating Pipes with Free Convection*)

The sludge digestion tank shown in Figure 2 is to be provided with heat by means of a spiral-form horizontal heat exchanger. This problem is a continuation of Problems 1 and 2, the three problems comprising a comprehensive solution of a sludge digestion heating application. Pertinent data are as follows:

Heat required ..... = 256,900 B.t.u./hr.
Tank Floor to bottom pipe. = 6 feet
Vertical spacing of pipes.. = 12 inches
Mechanical Agitation ..... = None
Convection ..... = Free
Temperature of Sludge.... = 85°F.
Temperature H.W. Supply. = 130°F.
Temperature H.W. Return. = 110°F.
Circulating Water ..... = Well water, 100 ppm hardness

From Equation (18)

$$Q = \frac{256{,}900}{(130 - 110) \times 500} = 26 \text{ g.p.m.}$$

Since the base coefficient f_b for the inside film depends upon the velocity of flow through the pipe, it is necessary to assume a pipe size which appears in advance to fit the conditions. If the heat exchanger based upon this pipe size is found to be unbalanced, a second calculation must be made for another pipe size. If a 2½ inch internal diameter, wrought iron pipe is assumed, then the velocity of the hot water through the pipe is 1.68 ft./sec. Since this is greater than .049 ft./sec., the flow is turbulent (see Equation 10).

The inside film coefficient f_i can be obtained from Case 1, and the outside film coefficient f_o from Case 3. From Figure 7, $f_b = 410$ B.t.u./hr./sq. ft./°F.; from Table 5 by interpolation, F_t for 120° F = 1.12; from Table 6, F_d for 2½ inch pipe = 0.83. Hence,

$f_i = 410 \times 1.12 \times 0.83$
$= 382$ B.t.u./hr./sq. ft./°F.

The average temperature difference ΔT_o, inside to outside water, is $(120 - 85)/2 = 17.5°$ F. From Figure 8, $f_b = 95$ B.t.u./hr.; from Table 9 by interpolation, F_t for 85° F. = 0.86; from Table 10, F_d for 2½" pipe = 0.77. Hence,

$f_o = 95 \times 0.86 \times 0.77$
$= 63$ B.t.u./hr./sq. ft./°F.

The inside and outside scale coefficients can be obtained from Table 13.

$S_i = 500$ B.t.u./hr./sq. ft./°F.
$S_o = 70$ B.t.u./hr./sq. ft./°F.

Thus in Equation (17)

$$U = \frac{1}{\frac{1}{382} + \frac{1}{63} + \frac{1}{500} + \frac{1}{70}}$$

$= 28.8$ B.t.u./hr./sq. ft./°F.

The total effective area of heating pipe surface required to transmit 256,900 B.t.u./hr. can be obtained from Equation (13)

$$H = AU(\Delta T_m)$$

and

$$A = \frac{H}{U(\Delta T_m)}$$

$$= \frac{256{,}900}{28.8 \times (120 - 85)}$$

$= 255$ sq. ft.

The external area of 2½ inch wrought iron pipe is .753 sq. ft. per foot of length. The minimum length of heating pipe required will be 255/.753 = 338 lineal feet.

One spiral pipe coil of 39 ft. diameter (1 ft. less than the inside diameter of the sludge digestion tank) has a length of 123 lineal feet. Thus, the minimum number of coils required is 338/123 = 2.8.

A heat exchanger consisting of 3—39-ft. diameter coils of 2½ inch wrought iron pipe will satisfy the requirements of the problem if 26 g.p.m. of 130° F. water is circulated continuously.

Illustrative Problem 6 (*Design of Heat Exchanger—Vertical Bank Type of Unit with Forced Convection*)

The sludge digestion tank shown in Figure 4 is to be provided with heat by means of a vertical-bank type of heating unit. The sludge will be stirred by a vertical stirrer with stirring blades as shown in Figure 6. Pertinent data are as follows:

Heat required ..... = 256,900 B.t.u./hr.
Spacing of pipes ..... = 6 inches
Mechanical agitation ..... = Rotary Stirrer, 60 r.p.m.
Convection ..... = Forced
Temperature of Sludge..... = 85°F.
Temperature of H.W. Supply = 130°F.
Temperature of H.W. Return = 110°F.
Circulating Water ..... = Well water, 100 ppm hardness

From Equation (18)

$$Q = \frac{256{,}900}{(130 - 110) \times 500} = 26 \text{ g.p.m.}$$

If a 2½ inch internal diameter pipe is assumed as in Problem 5, the velocity of the circulating water will be 1.68 ft./sec. The inside film coefficient f_i can be obtained from Case 1, and the outside film coefficient f_o from Case 5.

From Figure 7, $f_b = 410$ B.t.u./hr./sq. ft./°F.; from Table 5 by interpolation, F_t for 120° F. = 1.12; from Table 6, F_d for 2½ inch pipe = 0.83. Hence

$f_i = 410 \times 1.12 \times 0.83$
$= 382$ B.t.u./hr./sq. ft./°F.

The distance from the stirrer shaft to the center of the vertical heat exchanger is 5 feet. Since the speed of the stirrer is 60 r.p.m., the peripheral velocity of the liquid through the heat exchanger will be from Equation (11)

$$V = \frac{\pi\sqrt{10} \times 60 \text{ r.p.m}}{60}$$

$= 10$ ft./sec.

From Figure 7 (Case 2), $f_b = 1800$ B.t.u./hr./sq. ft./°F.; from Table 7 by interpolation, F_t for 120° F. = 1.06; from Table 8, F_d for 2½ inch pipe = .63. Hence, from Case 5

$f_o = 1.2 \times f_{s.t.}$
$= 1.2 \times 1800 \times 1.06 \times .63$
$= 1450$ B.t.u./hr./sq. ft./°F.

The inside and outside scale coefficients can be obtained from Table 13.

$S_i = 500$ B.t.u./hr./sq. ft./°F.
$S_o = 70$ B.t.u./hr./sq. ft./°F.

Thus, in Equation (17)

$$U = \frac{1}{\frac{1}{382} + \frac{1}{1450} + \frac{1}{500} + \frac{1}{70}}$$

$= 56.0$ B.t.u./hr./sq. ft./°F.

The total effective area of heating pipe surface required to transmit 256,900 B.t.u./hr. can be obtained from Equation (13)

$$H = AU\ (\triangle T_m)$$

and

$$A = \frac{H}{U\ (\triangle T_m)}$$

$$= \frac{256{,}900}{56.0 \times (120 - 85)}$$

$$= 131 \text{ sq. ft.}$$

The external area of 2½ inch wrought iron pipe is 0.753 sq. ft. per foot of length. The minimum length of heating pipe required will be 131/.753 = 174 lineal feet.

Each vertical pipe in the bank-type heat exchanger has 25 feet of its length immersed in the liquid to be heated. The horizontal hot water supply and return pipes will have a minimum length of 20 feet from the heat exchanger to the tank wall. Thus, the total length of effective 2½ inch piping, if six vertical pipes are used in the heat exchanger, will be

Heat exchanger—25 × 6	= 150 lin. ft.
H. W. supply and return—20 × 2	= 40 lin. ft.
Total effective length	= 170 lin. ft.

This heat exchange piping will meet the requirements of the problem if 26 g.p.m. of 130° F. water is circulated continuously.

SELECTION OF HEATING EQUIPMENT

Standard equipment and control devices for heating hot water are too well known to warrant much discussion here. The usual sources of heat are conventional coal, oil, or gas-fired hot water boilers. A great majority of municipal sewage treatment plants use one or more of these. However, in many industrial plants, low-cost steam or electric current is available, and in such cases it is usually much more economical to use these sources of heat than it would be to recover the gases of sludge digestion for heating purposes, or to use any auxiliary fuel.

Where steam is used as a prime source of heat, the digestion tank circulating water can be heated automatically to any desired temperature by means of an instantaneous type of shell and tube hot water heater. With this type of heater the steam is introduced in the shell, and the hot water is circulated through the tubes. The quantity of steam admitted into the heater is controlled by a thermostatically-operated steam valve.

Where electric current is used as a prime source of heat, large capacity electric circulation heaters are used. These heaters have limited storage capacity, and depend entirely upon the heating element to be of a size sufficient to heat the water as it is circulated through the heater. A thermostatically-operated switch controls the amount of electric current applied in order to maintain the hot water within a predetermined temperature range.

Hot water circulating pumps are almost mandatory in order to insure a positive circulation of the proper quantity of hot water through the digestion tank heat exchanger at all times. Such circulating pumps may be manually controlled, but it is preferable to operate them automatically by means of a thermostatic switch of the Minneapolis-Honeywell or Mercoid Corporation type. The actuating temperature in this arrangement must be the temperature of the digestion tank liquid which is being heated.

REFERENCES

1. Keefer—"Large Scale Sludge Digestion Experiments at Baltimore," Water Works & Sewerage, Pg. 81 (Mar., 1933).
2. Downes—"Gas Collection and Sludge Heating," Sewage Works Journal, Pg. 72 (January, 1932).
3. Standards of Heat Exchange Institute, published by Heat Exchange Institute, New York City, 1937.
4.* Rawn—"Sludge Digestion Temperature Control With Live Steam." Water Works and Sewerage (July, 1942).

*Added by the editors. An article published since author's preparation of this paper.

The Sewage Works Federation

Things You Should Know About It

By W. H. WISELY
Executive Secretary

What is the Federation? The Federation of Sewage Works Associations is a non-profit, international organization founded in 1928, now comprising 26 member associations.

Objectives of the Federation. "The advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes; the design, construction, operation and management of treatment works; the study, promotion and encouragement of improved sanitation of waterways; the correlation and strengthening of regional and state sewage works associations within or without the United States of America; the publication of the *Sewage Works Journal;* and other relevant activities."

Benefits of Membership: All members receive the *Sewage Works Journal,* official publication of the Federation and an outstanding reference source. It is published every other month.

The annual convention of the Federation and the regular interim meetings of the member associations offer unusual opportunity for the exchange of information and fellowship among others of like interest.

Through the activity of the Federation committees, advancement in the entire field and welfare of those engaged therein is derived. Committee functions include: Awards for Outstanding Achievements; Public Relations; Sewage Works Practice; Research; Operation Reports and Records; Operator's Qualification and Welfare; War Problems.

Manuals of Practice now in preparation are: Sewage Sludge as Fertilizer; Sewer Maintenance, and Air Diffusion in Sewage Works.

Sewage Works Journal: Edited by Dr. F. W. Mohlman, Director of Laboratories of the Sanitary District of Chicago, the Journal averages about 1,100 pages of text annually. Over the past seven years a break-down of text material carried in the Journal is as follows: Sewage works operation, 35.6 per cent; sewage research, 31.6 per cent; industrial waste treatment, 6 per cent; reviews and abstracts, 8 per cent; Federation and Member Association News, 13.8 per cent.

A special feature of the Journal is the "Operators' Corner", a highly practical section of about 40 pages each issue.

How to Become a Member: Any individual interested in sewage and waste disposal is eligible to membership by joining any one of the member associations. It is customary to join the member association in the territory in which one resides, but where residence or employment is not in the territory of any existing member association, the applicant may apply to any association he may choose. Application blanks may be secured from the Secretary of member associations or from the office of the Secretary of the Federation, Box 18, Urbana, Ill. Any governmental unit or other corporation or organization (not an individual) may affiliate by becoming a Corporate Member.

Annual Dues: For membership the annual dues are set by the individual member associations and vary from about $4 to $6 per year for Active Members. Corporate Member dues are also established by the member associations and vary from $11 to $15 per year. Of the Active and Corporate dues, $3 and $10, respectively, goes to the support of the Federation activities and to cover the subscription to the *Sewage Works Journal.*

All persons interested in bettering their status individually and the enhancement of their professional standing should become affiliated with the Federation of Sewage Works Associations. For further information write to W. H. Wisely, Executive Secretary, Federation of Sewage Works Associations, Box 18, Urbana, Ill.

The Editor's Comments

Going Up!

"GOING UP!" It wasn't the words of the elevator operator that struck me. It was the way she said it,—with a positive air, an assurance. An assurance that here, definitely a car was going up. No question, no hesitancy, no hint that it would ever come down again.

Immediately there flashed to mind something else that is going up—very positively going up—and this is membership in the American Water Works Association, and in the Federation of Sewage Works Associations.

It is definitely reassuring to know that membership in these two organizations is showing a continual growth. At nearly all of the recent Water Works Sectional meetings the chairman of the membership committee has reported a gain in members during the year with further additions during the meeting. Records from Harry Jordan's office show a healthy gain in members. Illinois and Canada are now battling for third place, Ohio has passed the 200 mark, and Indiana is near it. Other sections too show marked growth. Such a gain indicates a faith in the future, and a belief in the importance and value of membership in AWWA. *But*, that there is opportunity for further growth is evident from the registration lists of many of the sectional meetings. There are usually a goodly number of non-members on the list, and it may be observed also that there are several persons who do not register at all. In this we are not referring to manufacturer's representatives, but to water works operators and engineers.

In the Federation of Sewage Works Associations, Secretary Wisely reports that membership is now ahead of this time last year. Younger than AWWA and only recently organized as a national group of sewage works operators and engineers, the Federation is naturally the smaller of the two. It also has a smaller field to draw from at present, but post war expansion of sewage plants should remedy that. In spite of war, and limited size of field, the Federation is growing thanks to the various association secretaries and the work of Mr. Wisely.

We hope that neither Mr. Jordan or Mr. Wisely will ever have to say anything but "Going Up!" when asked about memberships in their organizations.

And—Bigger and Better

The first editorial on this page was written by Dr. Symons. It represents the maiden contribution to this page by our new Associate Editor. This being an especially important issue (to us at least) and "Doc" having worked shoulder to shoulder with Ye Ed. into the wee hours a number of nights, to get this heavy issue ready for distribution on schedule, was given opportunity to choose his own topic for an editorial.

Interestingly enough the same topic, in general, would have been chosen for this page had "Doc" not selected it also. With this number issuing at the time of the 1943 convention (Second Wartime Conference) of A. W. W. A. it was only natural to be thinking of the progress made over the wartime years by A.W.W.A.—and, more particularly, thinking of what the Association officers and headquarters staff have accomplished in the interest of members of A.W.W.A.; and, moreover, to the benefit of the entire water works profession of the Country. The information and beneficial advice which has been secured through close and frequent contact with a number of Federal agencies and officials in Washington by A.W.W.A.'s Harry Jordan and President Abel Wolman, and with beneficial advice passed on at regular intervals to A.W.W.A. members, via special mailings as well as the monthly Journal, speaks for itself.

That such beneficial service and activities in Washington, looking to the best interests of water works management working toward assurance against possible costly failures of water supply, has been increasingly appreciated is probably no better shown than by the record of membership growth which A.W.W.A. has experienced during the year elapsed since the First Wartime Conference in June, 1942. Those who have been watching the month by month figures, revealing a comparison of new member gains with figures for previous months and years, can but be convinced that *"there must be a reason."* While this "Going Up!" process continues at increased pace, it is of equal significance to observe the markedly diminishing figures revealing those members dropping out.

Dr. Symons also brings into his editorial the much newer Sewage Works Federation, the membership of which is also "Going Up!", but with nothing like the number or the proportionate *rate* experienced by the Water Works Association. That the Federation has not gained members at a more impressive rate has to us been disappointing—and for this there is also to our thinking "a reason." Unlike the Water Works Association, which obtains its members direct, the Sewage Works Federation is ONLY *a federation of associations*. While the Federation operates under a Constitution and By-Laws, its Member Associations have dissimilar individual constitutions and by-laws of great variety. And there is the weakness that there is no uniformity in the annual dues or membership qualifications of the various federated associations. In the second matter the Federation exercises but little jurisdiction—and, on the matter of dues, *none*. Furthermore, an individual, as such, can not be offered the distinction of becoming a member of a National Sewage Works Association. This, because the Sewage Works Federation has no individual members. Instead, as a person, he can only become a member of one of the state or regional associations which comprise the Federation. Our thought is that these socalled member Associations are too "individualastic" for the best interests of the members or the sewage works profession, as a whole; or, for the Federation as a National enterprise. Others may not agree, but on this question time will tell.

Our further candid opinion is that the Federation, which because of the financial situation began with a half-time Secretary, can not without a full-time Secretary and adequately staffed headquarters office expect to give the type of service or attention to membership problems which it is going to take to create any *real* Federation strength. Since the Federation's financial status now seemingly will permit going forward with the original intent of putting a capable Secretary on a full-time basis, with adequate headquarters facilities to make the Federation click, such should be done without further delay.

A subsequent step would be that of establishing a more direct, intimate and meaningful contact between Federation headquarters and existing and potential members—members who should be members of the Federation, *in fact*, and paying uniform dues the country over.

MEETINGS SCHEDULED:

June 15-18—CLEVELAND, O. (Statler & Carter Hotels). 1943 A.W.W.A. (Wartime Water Works Conference). Executive Secretary, Harry E. Jordan, 500 Fifth Ave. New York, N. Y.

June 23—MANSFIELD, OHIO (Mansfield-Leland Hotel). **Ohio Conference on Sewage Treatment.** Secretary, J. R. Turner, % Sewage Treatment Plant, Mansfield, O.

Sept. 16-17—DENVER, COLO. (Hotel to be selected). **Rocky Mountain Section, A.W.W.A.** Secretary, O. J. Ripple, Supt. Filtration, Littleton, Colo.

Sept. 22-23—PITTSBURGH, PA. (Roosevelt Hotel). **Western Pennsylvania Section A.W.W.A.** Secretary, Earle P. Johnson, Wallace & Tiernan Co., 418 Flannery Bldg., Pittsburgh, Pa.

Sept. 28-29—BOSTON, MASS. (Hotel Statler). **New England Water Works Association.** (Annual Convention.) Secretary, Frank J. Gifford, 613 Statler Bldg., Boston, Mass.

Sept. 30-Oct. 1—BINGHAMTON, N. Y. (Arlington Hotel). **New York Section A.W.WA.** Fall War Conference. Sec'y-Treas., R. K. Blanchard, 50 West 50th Street, New York City.

Oct. 11-13—OKLAHOMA CITY, OKLA. (Hotel Biltmore). **Southwest Section, A.W.W.A.** Secretary, Geo. J. Rohan, Supt., Water Works Municipal Bldg., Waco, Texas.

Oct. 12-14—NEW YORK, N. Y. (Hotel to be selected). **American Public Health Wartime Conference.** Executive Secretary, Dr. Reginald M. Atwater, 1790 Broadway, New York, N. Y.

Oct. 19-21—MILWAUKEE, WISC. (Plankinton Hotel). **Wisconsin Section A.W.W.A.** Secretary, L. A. Smith, Superintendent Water Works, City Hall, Madison, Wis.

Oct. 21-23—CHICAGO, ILL. (Hotel Sherman). **Federation of Sewage Works Association.** Annual Meeting, "War Time Conference." Secretary, H. W. Wisely, Urbana-Champaign Sanitary District, Urbana, Ill.

Oct. 27-29—LOS ANGELES, CALIF. (Biltmore Hotel). **California Section, A.W.W.A.** Secretary, H. Arthur Price, Box 3669, Terminal Annex, Los Angeles, Calif.

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Under Secretary of War Robert P. Patterson has just informed the men and women employees at Hooker that they have won the privilege of adding a coveted White Star to the Army-Navy "E" Production Award Flag which now flies above their plant.

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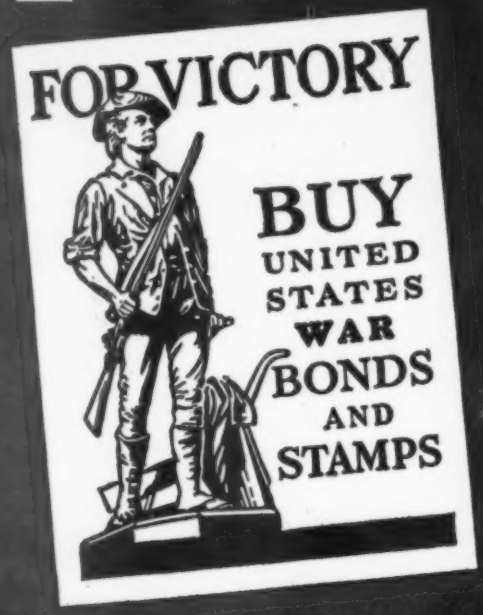

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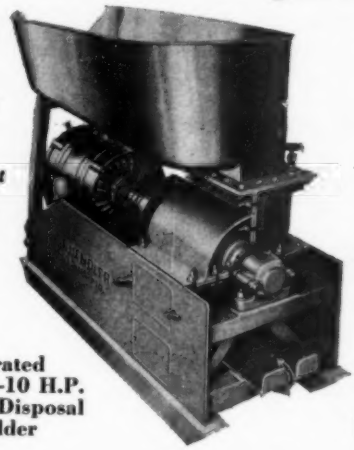

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WITH THE MANUFACTURERS

Lefebvre Made President Cooper-Bessemer

Announcement was recently made of the election of Mr. Gordon Lefebvre to the office of president and general manager of the Cooper-Bessemer Corporation.

Mr. Lefebvre, who joined Cooper-Bessemer some twenty months ago

Gordon Lefebvre

as vice-president and general manager, succeeds Mr. B. B. Williams, former president, who will continue his duties as chairman of the board.

Mr. Lefebvre is a graduate of the Virginia Polytechnic Institute and attended the U. S. Military Academy at West Point. Formerly with General Motors, Mr. Lefebvre had charge of production at Chevrolet plants under William S. Knudsen and later he was vice-president in charge of activities in Canada and subsequently of the Pontiac division. Immediately before joining Cooper-Bessemer Mr. Lefebvre was associated with the American Locomotive Co. in charge of the Diesel engine division. As a member of the Joint War Production Committee of the Economic Defense Board, he has been active in efforts toward coordinating the production of war materials in the United States and Canada.

Dow Establishes New Development and Service Division

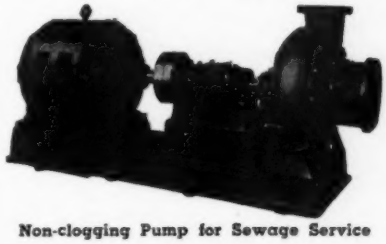
To Be Headed by D. K. Ballman

The organization of a new Development and Service Division has just been announced by The Dow Chemical Co.

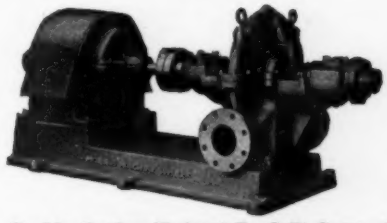
One of the major purposes of this new division is the study and further application of existing (standard) Dow products as well as the development and introduction of new products. It will be directed by D. K. Ballman, whose eight years of product development and technical

HOW TO SELECT LONG-LIVED PUMPS

There's an old . . . and well founded . . . medical saying that if you want to live long, pick out long-lived ancestors. On that basis alone, the Morris Pumps of today are assured of a long, useful life, for they have the same rugged constitution that has characterized their pump predecessors for more than two human generations. And in addition, the many refinements in design possessed by present-day Morris Pumps have produced remarkably high efficiencies that far exceed those which were formerly possible. Morris bulletins tell the whole story . . . write for copies on centrifugal pump types in which you are interested.



Non-clogging Pump for Sewage Service



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service work with Dow admirably fits him for his duties as head of this new division.

This development division, to be headquartered in Midland, Mich., will be staffed by a group of experts selected for their full technical knowledge of Dow products and specific industries. Within the new division will be consolidated the work which Dow Co. has previously been doing under several separate divisions. Now its efforts will be coordinated and intensified under one head.

The new division will take the initiative in contacting the technical men in other industries and will seek to develop a technical consulting service. It will call the technicians' attention to present and possible uses of old and new Dow products which may solve their problems; and, when there is no ready answer to a proposition which has promise Dow's research laboratories will go to work on it, according to Mr. Ballman.

The Dow Chemical Co., it is understood, already boasts a highly diversified line of more than 500 chemicals which have proven to be highly useful to industry, both in peace and in war.

Varec Appoints New Sales Engineers

The Vapor Recovery Systems Company of Compton, California, recently announced the following appointments as Sales Engineers:

Clifford T. Stanhope is in charge of the "VAREC" Eastern office and warehouse at 30 Church Street, New York City. Mr. Stanhope has had a wide experience in Petroleum, Chemical, and Pipe Line Activities at Okmulgee, Oklahoma; Ottumwa, Iowa, and East Braintree, Massachusetts. Later he was chief engineer for Cities Service Company at New York City and purchasing engineer for Nicaro Nickel Company at New York City. Mr. Stanhope is thoroughly grounded in servicing all problems relating to tank equipment and safety devices for the control of volatile liquids and combustible gases. Mr. F. F. Tentschert, a Sanitary Engineer of wide experience, will assist Mr. Stanhope in the Sewage and Marine Divisions.

Mr. Frank M. Holloway, formerly Eastern Sales Manager, will assume new duties as Southeastern Sales Manager, with headquarters at New Orleans, Louisiana.

Mr. John L. Shaunty has been appointed manager of Mid-Continent Sales, Distribution, and Service, in charge of both Houston and Tulsa

offices and warehouses. Mr. Shaunty has been connected with "VAREC" for a number of years, starting at the bottom.

A. J. Foley & Co., of Chicago, has been appointed "VAREC" representative in the Great Lakes Area for "VAREC" Sewage and Marine Equipment. Mr. Foley has long experience in oil refining, steam power, and sanitation plants, instruments, regulators, automatic control and safety devices and other engineering equipment.

"Bill" Johnson Made President of Phoenix Meter

Wm. H. Johnson

Wm. H. Johnson, who for the past several years has been manager of sales for the Phoenix Meter Co., has recently been made president and general manager of the company. He succeeds the late Victor Arnold as probably the youngest man to ever become president of any company in the waterworks field.

Mr. Johnson started with the Phoenix Meter Corp. 14 years ago as office assistant; four years later was placed in charge of the office and in 1936 made assistant to the president. In 1938 he became sales manager, and was elected secretary and treasurer in 1940.

"Bill" Johnson proved his ability as a very young sales manager, and we expect to see Phoenix move ahead under his management as head of this company, whose principal business is that of supplying water utilities direct with repair and replacement parts for various makes of meters.

Dresser 1943 Output Up Better Than 100 %

According to the recent quarterly letter to the shareholders of the Dresser Manufacturing Co. and subsidiaries, the combined sales of these organizations for six months to April 30 were more than for the entire year of 1942. This means a greater output of materials in war production. Included in such war production output are shell casings, heavy gun carriages, Diesel engines, pumps for hot oils and for chemicals used in the production of synthetic rubber, compressors and other power producing units.

Right now, our job is to produce better and more portable gasoline-engine-driven generators than our enemies—Germany, Italy and Japan. It's our biggest job. We are faced with tough competition. But it will help us and help you. To meet the ever-increasing demands of the Army and Navy, we have made many important improvements in our units and we have multiplied our production several times over. This means better and more Homelite Portable Generators for your use after the war.

We're meeting the demands of the military forces with flying colors. We'll be ready to meet your demands, with equal success, when peace is finally declared.

HOMELITE CORPORATION

PORT CHESTER, NEW YORK

PHOENIX
DISC WATER METERS
featuring HELICAL GEARS
(A Phoenix Patent)

Twenty-Eight Years of Accurate, Dependable Service Attest to the High Standard of Excellence of Phoenix Products.

Now Furnished with Cast Iron Cases to Divert Critical Materials to War Products. Parts Interchangeable.

ADEQUATE STOCK OF REPLACEMENT PARTS

Registers • Gear Trains • Disc Chambers
Disc Pistons • Bottom Cases • Casing Gaskets •
Gears • Casing Bolts, Nuts and Washers.

Write for Catalog

PHOENIX METER CORPORATION

PRINCE BAY • STATEN ISLAND • NEW YORK

WE SERVE THOUSANDS OF SATISFIED CUSTOMERS

SPARLING
Water Measuring Equipment

Consistent Accuracy
Ease of Installation
and Maintenance
Low Pressure Loss

Box 3277 Terminal Annex	LOS ANGELES
3104 Michigan Avenue	CHICAGO
622 Broadway	CINCINNATI
101 Park Avenue	NEW YORK
6 Beacon Street	BOSTON

SAVE *with* TENNESSEE CORPORATION Ferri-Floc

Be sure to turn to Page 216 in the Reference & Data Section.

TENNESSEE CORPORATION
Atlanta, Georgia Lockland, Ohio

Rehabilitation of Water and Sewage Equipment by Metallizing

From Alberta, Canada, comes the story of a ten day repair job done in 24 hours by metallizing. The phosphor bronze packing glands of a 12 M.G.D. centrifugal pump, supplying water to a western Canadian city, were deeply scored on the outer ends. New sleeves would have had to be ordered from Scotland and would have required at least ten days for installation. By using a metallizing gun, the sleeves were restored to original condition in 24 hours without removing any part of the pump but the housing.

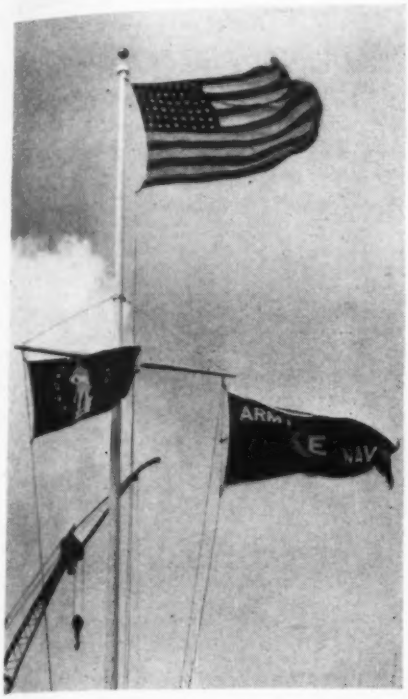
The metallizing process has also been put to effective use in the repair of plug cocks. Types of abrasion which these valves used in a distillery are not unlike those observed in sewage treatment plants. Such plug cocks are costly and difficult to replace. As a stop-gap in replacement while new plug cocks were being ordered through priorities, metallizing was tried. The story of the success of metallizing these valves, first with copper and later with Sprabronze T, was told by Mr. L. L. Baille, Plant Engineer of Hiram Walker & Sons in Peoria. It was a prize winning story for Mr. Baille, and what it says may well be of interest to water and sewage plant operators and engineers having plug valves in their plants.

Where machine shops are available and proper temperature control is possible, this method of rebuilding and repairing worn parts of bearings, sleeves, valves and other equipment suffering abrasion, offers the water or sewage plant surcease from the sorrows of replacements in these times of scarcity. The complete story of these applications is told in the March-April issue of the "Metco News," published by the Metallizing Engineering Co. of Long Island City, New York.

More "E" Awards

During the month of May announcement was made by the War Department of the award of Army-Navy Production "E" Awards to the following firms familiar to our readers: Mueller Co. of Decatur, Ill.; Badger Meter Manufacturing Co. of Milwaukee; Link-Belt Co. of Chicago (two plants); Resinous Products and Chemical Co. of Philadelphia; Chicago Bridge and Iron Co. (Seneca plant); and the Niagara Alkali Co. of Niagara Falls, N. Y.

The Flagpole of Chicago Bridge's Eureka Plant



Proud are the officials of Chicago Bridge and Iron Co. and employees of their Pacific Coast plant, from the flagpole of which now flies the Army-Navy "E" Pennant of accomplishment in production, as well as the Minute Man flag, denoting that at least 90% of the plant's officers and employees are monthly purchasing Victory Bonds to the extent of 10% of their earnings.

As we go to press word has come of the award of the Army-Navy "E" also to Chicago Bridge's Seneca plant near Chicago. This last award was made on May 29th.

Pittsburgh's "Cappy" Higgins Returns to Air Corps as Major

A. E. Higgins, Vice-President and Sales Manager for the Pittsburgh Equitable Meter Co. and Merco Nordstrom Valve Company of Pittsburgh, Pa., was commissioned Major in the U. S. Air Corps on May 8, and called immediately for active duty.

Maj. Higgins

A veteran of World War I, Major Higgins has held a reserve officer's commission for many years. In 1918 he qualified as an army air pilot and has since flown his own plane throughout his business career, and reenters the air corps with over 6,000 hours solo credit.

Prior to associating with Pittsburgh Equitable and Nordstrom Valve he served as secretary for the natural gas department of the American Gas Association.

R. M. Simon of R. D. Wood Co. Dies

R. M. Simon, age 48, New England representative of R. D. Wood Co. since 1920, died at his home in Worcester, Mass., on May 18th.

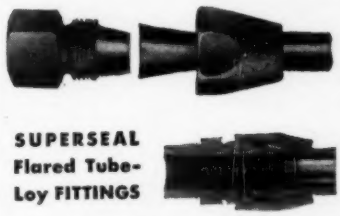
He was a native of Philadelphia, a veteran of World War I and had been in the employ of R. D. Wood Co. for the past 30 years.

ASARCO Type K Tube-Loy and SUPERSEAL Flared Fittings for Main to Meter Water Service

Have you been stymied getting materials for Main to Meter Water Service?

Here's your answer . . . ASARCO Type K Tube-Loy and SUPERSEAL Flared Tube-Loy Fittings. This combination, made of less critical materials, offers the advantages of easy handling for fast installation, long life, leak-proof connections and trouble-free service PLUS *availability right now.*

For complete information and descriptive catalog on SUPERSEAL Flared Tube-Loy Fittings and ASARCO Type K Tube-Loy, call your nearby GRINNELL BRANCH or write Grinnell Company, Inc., Executive Offices, Providence, R. I.



SUPERSEAL Flared Tube-Loy FITTINGS

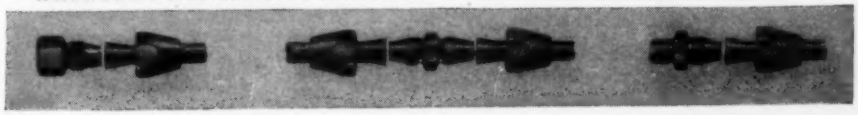
- ★ Made of malleable iron, electro galvanized.
- ★ Long, 10° tapered cone provides greater seating area for tubing flare . . . forms a leak-proof joint unaffected by vibration.
- ★ Three types available – tube to inside iron pipe thread . . . tube to outside iron pipe thread . . . tube to tube.
- ★ Specially designed for use with

ASARCO Type K TUBE-LOY

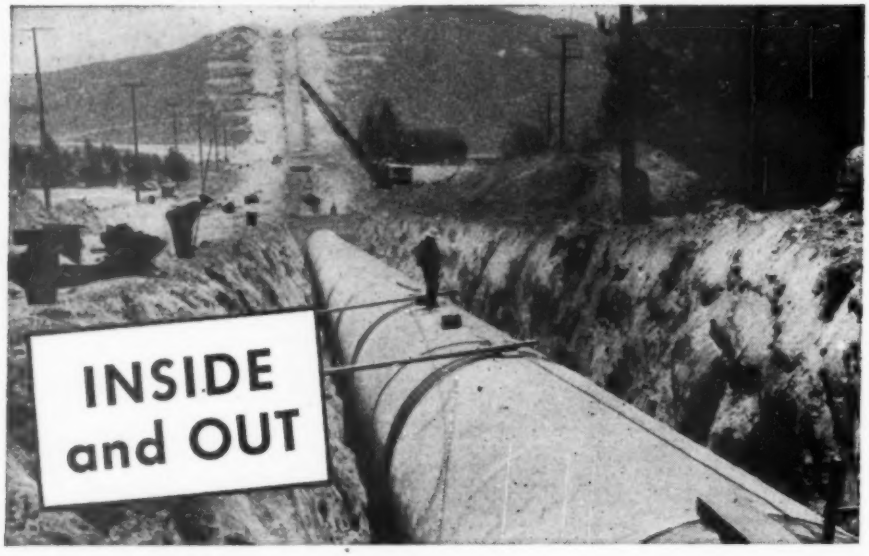
- ★ Tubing extruded from a lead alloy . . . has all of lead's unexcelled resistance to corrosion.
- ★ Installation is much easier than with other available materials.
- ★ Nominal sizes – ½", ¾", 1".

GRINNELL

WHENEVER **PIPING** IS INVOLVED



☆ Dependable Protection



With REILLY PIPE ENAMEL

Booklet describing REILLY *Protective Coatings will be sent on request.*

Pipe lines coated with REILLY ENAMEL give long and dependable service and low maintenance costs in all types of soil and under wide extremes of temperature. The tough, durable REILLY coating effectually prevents corrosion from moisture, electrolysis, soil acids and alkalies; resists abrasion and soil stress, and will not crack in sub-zero cold or sag in tropical heat. . . . As an inner lining on water mains, REILLY ENAMEL protects against incrustations and tuberculation and assures full-capacity flow for the life of the pipe. . . . On storage tanks, structural steel work and other metal surfaces REILLY Coal Tar Paints give effective, economical protection against corrosive vapors and gases.

REILLY TAR & CHEMICAL CORPORATION

Executive Offices: Merchants Bank Building, Indianapolis, Indiana

2513 S. DAMEN AVENUE, CHICAGO, ILLINOIS — 500 FIFTH AVENUE, NEW YORK, N. Y. — ST. LOUIS PARK, MINNEAPOLIS, MINN.

SEVENTEEN · PLANTS · TO · SERVE · YOU

Prevent wear and cutting of rods, plungers, shafts and valve stems by using

MABBS RAWHIDE PACKING

In Your Water Works and Sewage Plants

IT LASTS LONGER — *Is Anti-Frictional, Saves Power, Labor and Repairs. Will prove the cheapest packing that can be bought.*

Trade Mark Reg. U. S. Pat. Off.

Mabbs Hydraulic Packing Co.

Incorporated 1892

481 S. Dearborn St., Chicago, U. S. A.

EDSON DIAPHRAGM PUMPS

Hand Sizes 2″, 2½″, 3″, 4″
Power Sizes 3″ and 4″
Open Discharge or Force Pump
Edson Special Suction Hose
Red Seal Diaphragms
Strainers and Foot Valves
Hose Spanners—Adapters

THE EDSON CORPORATION

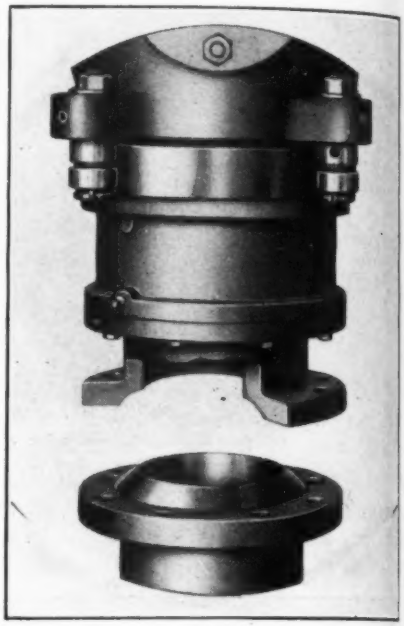
Main Office and Works: 49 D St. South Boston, Mass.

New York: 142 Ashland Pl., Brooklyn

EQUIPMENT NEWS

Yeomans Leveler for Rotary Distributors

Among new items of sewage treatment equipment on which patents have recently been issued, is the Yeomans Leveler for restoring the vertical position of a distributor which tends to get out of alignment.



It is not uncommon for a trickling filter structure with rotary distributor, after several years of service, to settle out of level due to bad subsoil or other conditions. Besides any ill effect on drainage efficiency due to inclination of the bed, the stresses set up by unbalanced operation will soon cause serious damage to the thrust and guide bearings in the distributor—and must inevitably destroy them unless the condition is corrected.

In a distributor of the general type with an outer column carrying the arms rotating about an inner column on which it is mounted by thrust and guide bearings, it is clearly essential that the two columns be in concentric relation to each other. In the event of axial misalignment resulting in damage, it becomes necessary to dismantle the machine, break the inlet pipe-joint at the bottom, relevel and regrout the base fitting and reassemble the distributor.

The Yeomans Leveler makes it possible to restore the vertical position of the distributor as a unit with ordinary wrenches without any dismantling.

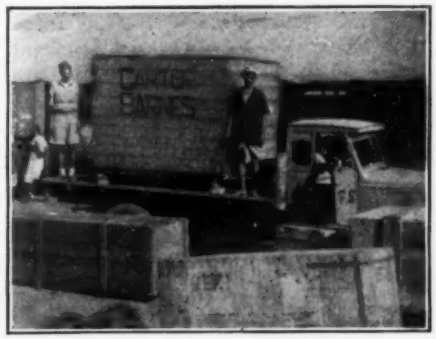
The leveler is so designed that a means is provided by which the entire distributor mechanism can be tilted several degrees in any desired direction and then locked in that position.

Where the Yeomans Leveler is to be applied to an existing distributor it is built as a complete sub-assembly with special flanges to be inserted between the base fitting and column flange already in place. This requires raising the distributor assembly but does not involve disturbing the base fitting or breaking and repouring the inlet pipe joint. Reduction in operating head due to raising the distributor is not more than 6 or 8 inches.

For a further description of the new accessory for leveling rotary distributors write Yeomans Brothers Co., 1433 North Dayton St., Chicago.

Carter Pumps in India

The accompanying photograph was recently received by the Ralph B. Carter Co. of Hackensack, N. J.,



with the following letter from the Calcutta Fire Brigade, Calcutta, India, dated Feb. 15, 1943.

Dear Sirs: I expect this photograph of one of the many offerings which came rolling into Harah Goods Yard will be of interest to you. Yours faithfully, Company Officer W. E. Marter (Ex. N.F.S., London).

The Carter-Barnes Co., composed of the Ralph B. Carter Co. and the Barnes Pump Co. of Mansfield, Ohio, had a contract for 1,000 of these Carter "Chiefs" with a capacity of 500 g.p.m. at 125 lb. pressure, driven by Chrysler industrial engine and mounted on a rubber tired trailer. The photograph is visual proof that these units are getting where they will do some good. U-boat commanders please note!

After Victory....

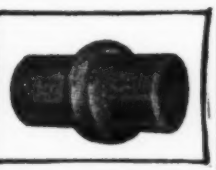
A WATER WASTE SURVEY NOW WILL TAKE CARE OF ABNORMAL DEMANDS ON THE WATER SYSTEMS FOR THE DURATION

A PITOMETER DISTRIBUTION STUDY. If the existing water system proves inadequate to supply such a huge increase of new users as some cities face, a Pitometer Distribution Study will result in a construction program economical of men, money and materials.

A PITOMETER WATER WASTE SURVEY will locate hidden leaks and other sources of waste. If waste is eliminated, additional expenditures for new pipe lines, standpipes, pumps, etc., may not be necessary.

THE PITOMETER COMPANY
ENGINEERS
52 CHURCH STREET, NEW YORK

WESTON



GASKET AND FORM
The Perfected Method for Making
SEWER PIPE JOINTS OF CEMENT
- No jute used—gasket centers spigot.
- Definite space in each joint for cement.
- Form confines cement-grout to lower portion of joint.
- Particularly advantageous in water-bearing trenches.
- Infiltration minimized.

L. A. WESTON Adams, Mass.

IMPROVED JOINTING COMPOUND
Tegul-MINERALEAD
for Bell & Spigot Main

- Sulphur base; quick sealing, speeding laying and backfilling.
- 10 lb. ingot form, easily handled, stored and shipped. Impervious to rain. Cannot change composition.
- Makes permanently tight joints. Goes 3 to 5 times as far as lead, helping conserve a strategic war metal.
- For money-saving information, write

The ATLAS MINERAL Products Company of Pa.
Mertztown Pennsylvania

WATER WORKS AND SEWAGE DISPOSAL PLANTS can maintain their efficiency of operation and protect their property . . equipment . . supplies and other valuable material against damage from backwater and sewage. This can be accomplished permanently with the Josam SIDE SWING OPEN SEAT BACKWATER SEWER VALVE which is "SUPER-SENSITIVE TO THE SLIGHTEST BACKFLOW."

- No retarding of flow because the pointed pivot cone bearings permit flap to swing wide open to full inside diameter of valve . . .
- Bearings are self cleansing . . . Highly sensitive . . . will not corrode or stick . . .
- The tight closing seat . . . revolving disc . . . offset at valve seat preclude fouling . . .
- Valve is normally open permitting continuous flow of water and circulation of air . . . extra vent unnecessary, but is so designed that it can be adjusted to form a closed seat when desirable.

WRITE FOR COMPLETE DESCRIPTIVE LITERATURE

JOSAM MANUFACTURING CO.

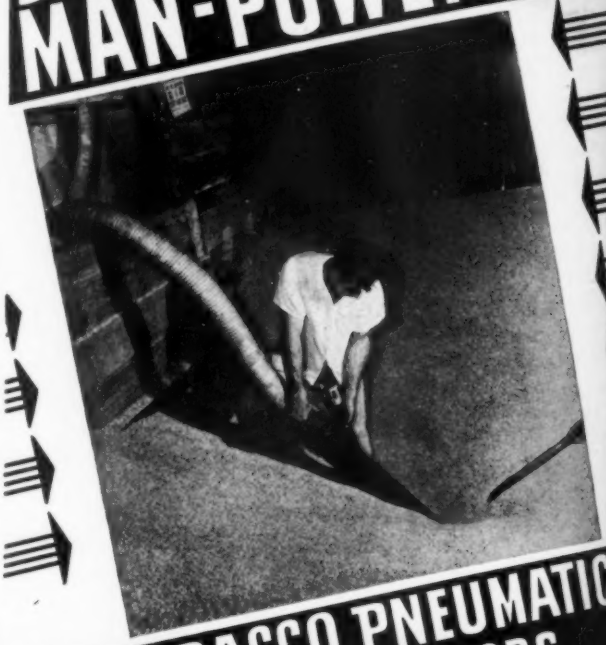
Manufacturing Division
Michigan City, Indiana

Executive Offices
Cleveland, Ohio

Branches in all principal cities

Josam PRODUCTS
STANDARD OF AMERICA

Save . . . MAN-POWER



With DRACCO PNEUMATIC CONVEYORS

The following Chemicals are efficiently and economically handled by DRACCO Pneumatic Conveyors in Water Works and Sewage Treatment Plants located in all parts of the country. Alum, lime, soda ash, bauxite, ferrous sulphate, pebble lime, activated carbon, and ammonium sulphate.

A PARTIAL LIST OF *DRACCO* INSTALLATIONS

FRIDLEY FILTRATION PLANT	Minneapolis, Minn.
DALECARLIA FILTRATION PLANT	Washington, D. C.
MUNICIPAL WATER SOFTENING PLANT	Sandusky, Ohio
MUNICIPAL WATER SOFTENING PLANT	Ames, Iowa
LEMIEUX ISLAND FILTRATION PLANT	Ottawa, Ontario
MAHONING VALLEY SANITARY DISTRICT	Niles, Ohio
MUNICIPAL WATER PLANT	Columbus, Ohio
MUNICIPAL WATER PLANT	Peru, Ill.
U. S. GOVERNMENT FILTRATION PLANT	Ft. Leavenworth, Kans.
MUNICIPAL WATER PLANT	Hamilton, Ohio
BACHMAN WATER PURIFICATION PLANT	Dallas, Texas
MUNICIPAL WATER PLANT	Richmond, Va.
MUNICIPAL WATER PLANT	Springfield, Ill.
MINNEAPOLIS-SAINT PAUL SANITARY DISTRICT (Sewage Disposal Plant, 2 installations)	St. Paul, Minn.
MUNICIPAL WATER PLANT (2 installations)	Milwaukee, Wis.
MUNICIPAL SEWAGE DISPOSAL PLANT	Oklahoma City, Okla.
MUNICIPAL SEWAGE DISPOSAL PLANT	Denver, Colorado
MUNICIPAL WATER PLANT	Covington, Ky.
MUNICIPAL WATER PLANT	Ann Arbor, Mich.
CLAYTON SEWAGE DISPOSAL PLANT	Atlanta, Ga.
SEWAGE DISPOSAL PLANT (2 installations)	Cleveland, Ohio
MUNICIPAL WATER PLANT	Benton Harbor, Mich.
MUNICIPAL WATER PLANT	Warren, Ohio
MUNICIPAL SEWAGE DISPOSAL PLANT	Detroit, Mich.
MUNICIPAL WATER PLANT	Flint, Mich.
CITY OF TORONTO WATER WORKS PLANT	Toronto, Ontario
WATER FILTRATION PLANT	Ottawa, Kansas
EL RENO WATER TREATMENT PLANT	El Reno, Oklahoma
CITY OF GRAND FORKS	Grand Forks, North Dakota
MUNICIPAL SEWAGE PLANT	Pittsburgh, Pennsylvania
WATER FILTRATION PLANT	Wichita, Kansas
INDIANAPOLIS WATER CO.	Indianapolis, Ind.
WATER FILTRATION PLANT	Appleton, Wis.
MUNICIPAL WATER PLANT	Chillicothe, Ohio

And a large number of installations in water works of Ordnance Plants.

Write for Bulletin No. 526

DRACCO CORPORATION

4079 E. 116th St., Cleveland, O. • New York Office, 130 W. 42nd St.

PNEUMATIC CONVEYORS • DUST COLLECTORS

"Eternit" a New Cement-Asbestos Pipe

The Ruberoid Co., New York, has recently introduced a specially fabricated form of asbestos cement pressure pipe for use in waterworks, drainage and irrigation systems, in chemical plants and pulp and paper mills, and other industrial plants.

The new product, called "Eternit" A/C pressure pipe, is created by a patented extrusion process which, in addition to providing density and strength, insures, without machining, uniform measurements and extremely smooth surfaces, both inside and out. The pipe can, when necessary, be cut in the field with a hack saw and be coupled immediately without further preparation—an important economy in time and labor.

Made from an exactly controlled mixture of asbestos fiber and Portland cement, Eternit pipe is not

subject to rust. Being a non-conductor of electricity, it is unaffected by stray ground currents and may be safely laid contiguous to electric light and power lines without danger of electrolytic or galvanic corrosion, regardless of the type of soil or the extent of moisture present. Immune to tuberculation and other forms of internal corrosion frequently caused by various ingredients of the liquid carried, the pipe is said to maintain a full-sized smooth passage, eliminating the expense of periodic cleaning or increasing pumping pressure to compensate for reduced diameters.

"Eternit" pipe exceeds by a safe margin the Federal specifications for this type of product. It is made in standard lengths of 13 feet and in diameters up to and including 6 inches. For further information, address The Ruberoid Co., 500 Fifth Ave., New York City.

Cross-section of Triturator showing renewable cutting teeth intermeshing with grates; also spring relief and adjustment provided for grates.
Cross-section showing assembly of cutter holders, spacers, and sealing discs on shaft, also its mounting on self-aligning ball bearings.

HE SHEARS ORGANIC SOLIDS INTO BITS

One of the many problems of sanitation engineering is the disintegration of solid organic screenings to permit their direct return to the sewage flow for subsequent settling and digestion.

For this function, Rex Mechanical Engineering—Rex M. E.—provides his Triturator. It cuts rags, paper and organic solids with a positive shearing action.

The lower drawing at top shows its assembly of cutter holders, spacers, and sealing discs on the shaft, and the mounting on self-aligning ball bearings.

The upper drawing shows the renewable cutting teeth in shearing contact with grates, also the spring relief and adjustment provided for the grates.

This Triturator, designed by Rex M. E., is a highly efficient, low-cost unit both from the standpoint of first cost and operating cost. It does its work with very low water and electric current consumption.

It meets squarely the exacting requirement resting upon all engineers: To produce maximum useful results with minimum cost. For complete information write Chain Belt Company, 1610 W. Bruce St., Milwaukee, Wis.

REX SANITATION EQUIPMENT

Triturators • Bar Screens • Tow-Bro Sludge Removers • Slo-Mixers Aero-Filters • Rapid Mixers • Grit Collectors and Washers

CHAIN BELT COMPANY OF MILWAUKEE

Member of the Water and Sewage Works Manufacturers Association, Inc.

BAILEY METERS AND CONTROLLERS

FOR SEWAGE TREATMENT AND WATER SUPPLY . . .

● Venturi Tubes, Weirs, Flumes, Nozzles and other primary elements; Mechanically and Electrically operated Registers and Complete Automatic Control Systems.

BAILEY METER COMPANY

1072 IVANHOE ROAD • CLEVELAND, O.

Bailey Meter Co. Ltd., Montreal, Canada

The Meter-Master

RATE RECORDER FOR WATER METERS

Send for Literature

F. S. BRAINARD & CO.

246 Palm Street, Hartford, Conn.

"R-C" POSITIVE DISPLACEMENT BLOWERS

—will handle more air per horsepower, and with less upkeep, than any other type of blower.

PLAN NOW— TO SAVE TIME, LATER

For the duration, Roots-Connersville production is dedicated to the job of "making it hot for the axis". Even though priorities may delay procurement of new aerating blowers for water and sewage treatment, we will be glad to help you work out the details of your needs now—for future action. Write for bulletin.

ROOTS-CONNERSVILLE BLOWER CORPORATION

306 Mount Ave.,
Connersville, Ind.

POSITIVE DISPLACEMENT moves more air
•
MODERATE SPEED means less wear

"R-C" Rotary Positive Blower used in water treatment process at Indianapolis Water Co. Capacity 300 CFM; 640 RPM; 5 lbs. pressure; V-belt driven from motor.

Roots CONNERSVILLE SINCE 1854 Aerating BLOWERS

☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆

Permanent . . . . .

REDWOOD PIPE Saves critical materials! Long known as a pipe with greater carrying capacity than metal or concrete. Does not clog, scale or pit.

WYCKOFF Since 1855

LOWER labor, installation and maintenance costs. Long life, no electrolysis, contamination of water, or destruction by sulphur, salt water or other mineral impurities. New type Wyckoff California Redwood Pipe for water supply and sewage lines is a proven product.

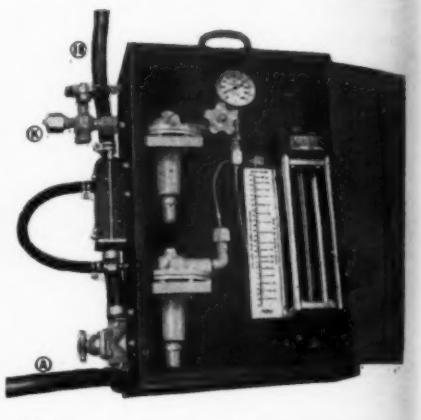
A. Wyckoff & Son Company

ELMIRA, N. Y.
Originators of Machine Made Wood Pipe
1855 — Our 87th Anniversary — 1942

☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆

New Portable Chlorinator by Everson

The Everson Manufacturing Co. of Chicago has recently introduced a portable chlorinator to be known as the "Evon" SterElator. This unit,



which is of compact construction, can be used either as a direct gas or as a solution feeder and may be carried as a portable unit or attached to a wall. The portable machine is useful for sterilization when water mains are extended, replaced or repaired, or when a pumping station is out of service, due to floods, breakdowns or other causes and an emergency supply needs chlorination. The unit may also be used in construction camps, logging camps, troop encampments or other places where water sterilization is desired but a permanent water plant is not justified. Industrial and manufacturing plants may also find use for a machine of this type, either for drinking water treatment or for the control of slimes in condenser tubes. Both the portable or wall model can be converted from direct gas feed to solution feed and vice versa by the simple operation of connecting one pipe and attaching or removing, as the case may be, a water supply hose.

Extractors for Broken Pipe Ends and Studs

Reps Pipe and Stud Extractors take much grief out of maintenance and repair jobs when it becomes necessary to remove the ends of broken pipes and bolts from their sockets.

These clever little extractors were designed and patented by a maintenance engineer and feature gripping without hammering, a four point bite grip, workability with a shallow grip and a pulling rather than a reaming action.

To remove a broken piece of pipe, insert the Reps Extractor properly

and turn with a wrench in the opposite directions of the threads on the pipe. To remove broken studs, drill a shallow hole in the exact center of the stud and insert the extractor

and turn in the opposite direction to the threads on the stud.

Reps Extractors are boxed in a set of ten with a convenient table inside the box cover to tell what number extractor to use for any size of broken pipe or stud. The sizes of drills needed for studs are also listed.

For additional information on this handy gadget, which has the earmarks of being a "friend indeed" when in need, write to the Reps Tool Co., Inc., 82 Wall St., New York, N. Y.

Leigh Willard Made A-C Director

Started with Company as Draftsman

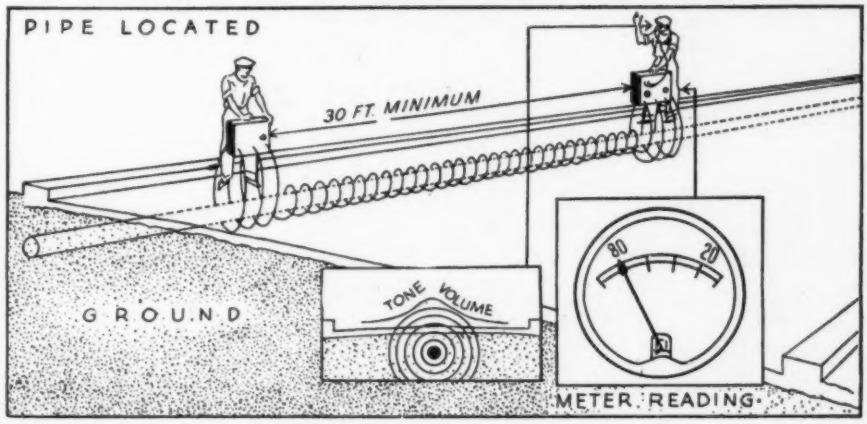
Leigh Willard, who came to Allis-Chalmers as a draftsman, was elected a company director at the annual meeting of stockholders. He will fill the vacancy left on the board by the death of Max W. Babb.

After serving A-C in various capacities for a number of years, Mr. Willard left to engage in the modernization of mechanical and electrical coal mining equipment, and later operated an industrial engineering office in New York. In 1927 he was placed in charge of engineering and construction for the Semet-Solvay Co., and later became its president.

The new director is also president and director of the Interlake Iron Corp., the largest producer of merchant pig iron in the nation, and is a director of the American Iron and Steel Institute.

M-SCOPE

BURIED PIPE AND CABLE FINDER



NO. 2—TO LOCATE A BURIED PIPE LINE

The M-Scope is solving—successfully—the varied problems involved in the development, operation and maintenance of buried pipe and cable systems and is in daily use by representative organizations in such important groups as:

Government Projects
Municipalities
Sewerage and Water Plants
Consulting Engineers
Airports
Public Utilities
Industrial Plants
Oil and Pipeline Companies

Watch for our series of monthly advertisements in W-W-&-S regarding the use of the M-SCOPE.

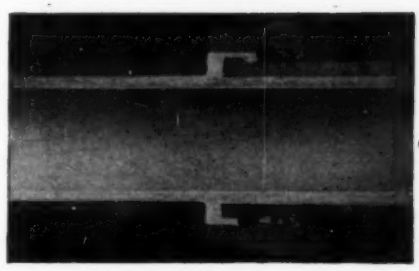
Send for Free Literature

FISHER RESEARCH LABORATORY

DIRECT TELETYPE BY POSTAL TELEGRAPH PALO ALTO, CALIF.

View showing Tate Process in Pipe Joint. Note thoroughness of Lining.

Help Save Critical Materials · investigate **TATE Cement Lining Process**



With the increase in demand for Critical Materials in the Water Works field *now* is the time to investigate the Tate Cement Lining process—and see what it can do to restore the efficiency of your old water mains.

THE TATE PROCESS ACCOMPLISHES

1. **Water mains cleaned and cement-lined without removing pipe.**
2. **Eliminates discoloration and further cleaning costs.**
3. **Reduces pumping costs.**
4. **Restores reduction in head and flow co-efficients. This means full fire protection and lowered insurance rates.**
5. **All Joints cement-lined . . . eliminates bacteria in joints.**
6. **Does the job with minimum interruption of service to consumer.**

Write for Literature

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84" pipe—Spring Lake, N. J.

FLANGED PIPE

FLEXIBLE JOINT PIPE

BELL & SPIGOT PIPE

SPECIAL CASTINGS

SHORT BODY BELL & SPIGOT SPECIALS

Large stock enables us to make prompt shipments.

CAST IRON PIPE

SIZES 2" TO 84"

Warren Foundry & Pipe Corp.

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75 Federal St., Boston

Economical-Effective Durable

SERVICISED
SEWER PIPE JOINTING COMPOUNDS

HOT POURED COMPOUND

Servicised Sewer Pipe Jointing Materials have served in the sewerage field through many years.

Our Hot Poured Compound is specially prepared for vitrified clay pipe used in sanitary sewerages.

Servicised Hot Poured Compound is quick setting and produces tough, flexible, long lasting joint connections. This material is shipped in Fiber Drum Containers that open very easily.

TUFFLEX . . . is a cold premixed troweling plastic material that is also widely used in jointing of vitrified clay pipe.

TUFFLEX is especially outstanding for use in wet trenches because the material will set under water, thereby assuring continuous pipe jointing.

The adhesive and cohesive qualities of this excellent compound are resultful in a highly waterproof and root repelling product.

Save time and labor cost by speeding up sewer pipe jointing with TUFFLEX. This material arrives on the job for immediate use.

Millions of pounds of Servicised Sewer Pipe Jointing Materials have been used throughout the country on Federal and Municipal Projects.

Pioneers in the Manufacture of Approved Construction Materials for Over 23 Years

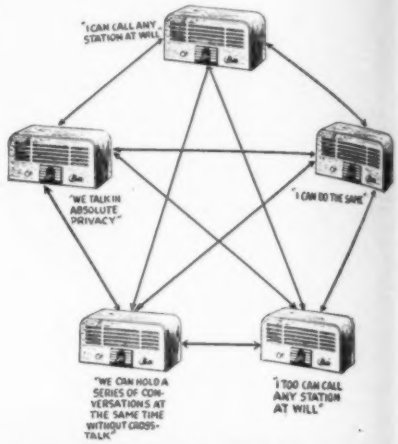
SAMPLES AND DESCRIPTIVE LITERATURE WILL BE SENT UPON REQUEST

SERVICISED PRODUCTS CORP.

6051 West 65th Street, Chicago, Ill.

"Talk-A-Phone" Intercommunicating Systems

A super chief Model Intercommunicating System is one of the new lines of the Talk-A-Phone Co. of Chicago.


"I CAN CALL ANY STATION AT WILL"
"WE TALK IN ABSOLUTE PRIVACY"
"I CAN DO THE SAME"
"WE CAN HOLD A SERIES OF CONVERSATIONS AT THE SAME TIME WITHOUT CROSS-TALK"
"I TOO CAN CALL ANY STATION AT WILL"

Incorporated in its design are many new features not heretofore used in such systems. One of these is the "Conference Traffic Control," which enables any number of stations to hold a private conference without interruption or eavesdropping from other stations. Another feature is the "Uni-Trans" or one way automatic transmission, especially effective for dictation of letters. Finger tip control, supersensitive amplifiers and optional privacy earphone are other characteristics.

Another newly developed system incorporates a feature of complete privacy for two communicating persons. This system known as the KS-60 Super Selective Model is made up of all master stations and permits a number of two way conversations to be held simultaneously without cross talk. Both of these systems are available to embrace from 2 to 8 stations. Bulletins on the systems, describing the installations, are available from the Talk-A-Phone Manufacturing Co., 1219 Van Buren St., Chicago, Ill.

LITERATURE AND CATALOGS

"Iron and Carbon Dioxide Removal by the Ferro-Filter" is the subject of Bulletin No. 252 of the American Well Works of Aurora, Ill. This bulletin deals with the removal of bicarbonate forms of iron and manganese and carbon dioxide by the use of the Ferrofilter.

Iron and undesirable manganese in water are usually accompanied by carbon dioxide, which must be removed to reduce corrosion. Iron and manganese are removed by two principal methods, aeration and lime-soda softening. The Ferrofilter removes all of these undesirable substances, supplanting coke tray aerator-sand filter combinations by carrying out the functions of both in one unit.

The Ferrofilter unit consists of a bed of graded anthracite media supported by a false bottom which forms a backwashable underdrain system. Water is applied to the surface of the media, in a thin wide film of uniform dosage by a rotary aerator.

Anthracite, having a smooth shiny surface, is easily washed free of oxidized iron and manganese deposits without incrustation. If the natural ventilation through the unit does not effect the desired carbon dioxide removal, auxiliary low pressure fan equipment may be supplied to increase the air flow.

Advantages claimed for the system include the removal of three undesirable substances in water by one operation and in one unit without the addition of chemicals. The Ferrofilter has also been used as a rapid rate trickling filter with recirculation to reduce the B.O.D., and to stabilize and aerate anaerobic supernatant liquor, and is proposed for the treatment of organic industrial wastes which lend themselves to treatment by aerobic biological processes. Appreciable B.O.D. reductions are noted on laundry waste treated in a Ferrofilter unit. A specification sheet is included in the Bulletin No. 252, which may be obtained from the American Well Works, Aurora, Ill.

Kapco Sewer Joint Compound is a product of the Keystone Asphalt Products Co., described in one part of a bulletin on paving products of this company. These sewer joint compounds are available either in

HAYS Thru 74 YEARS

Why Is The Trend Toward HAYS?

Hays dependability follows thru product and policy, a fact that is responsible for the ever increasing trend toward Hays Water Works and Sewerage Products. This twin policy established by our founders three quarters of a century ago has become a tradition at Hays. It has won new friends everywhere and we say if you have never tried Hays Products, ask a user nearby, for in almost every town and hamlet in the U. S. A., we can direct you to users who can tell you about Hays first hand.

Hays products are noted for their uniformity and dimensional accuracy which makes them interchangeable with any other standard water works connections. Write for copy of the Hays Water Works Catalog.

HAYS MFG. COMPANY, ERIE, PA.

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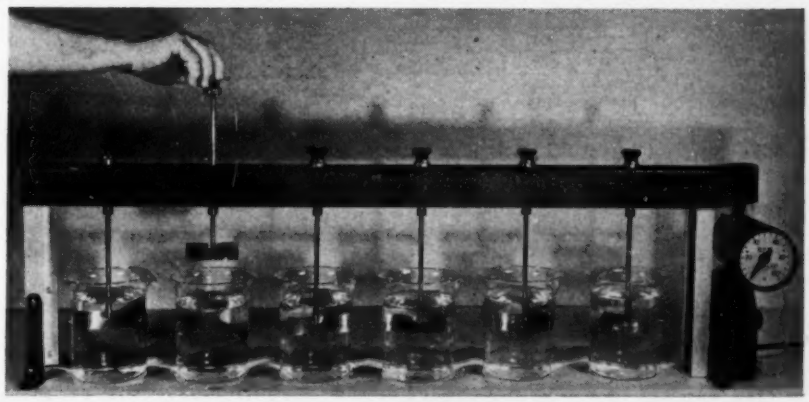
WATER WORKS PRODUCTS
HAYS
INVEST IN BONDS TODAY TO PROVIDE FOR EXTENSIONS TOMORROW



THE Phipps & Bird LABORATORY MIXER...

IS the important piece of equipment in the Modern Water Works Laboratory. Now being used by leaders in water works research. Many superintendents and chemists have been able to reduce their chemical costs by the control of chemical dosages with this mixer. Write for literature.

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WATER CONTROL EQUIPMENT

WRITE FOR THE CATALOGS ON THE EQUIPMENT IN WHICH YOU ARE INTERESTED

MUELLER CO.

MAIN FACTORY
DECATUR, ILL.

OTHER FACTORIES
CHATTA. TENN.
LOS ANGELES, CALIF.
SARNIA, ONT. CANADA

hot pouring form or cold troweling form. Basically these compounds are formulated with a combination of asphalt, asbestos, and special inert ingredients that will not shrink, crack or deteriorate with age. These special formulas permit the compounds to withstand all conditions encountered in modern sewer construction work. Packaged in convenient light weight fibre containers, eliminating return of drums and assuring full measure, these compounds have several other advantages including acid and alkali proof, root resistance, flexibility, reasonable cost, great strength, and resistance to disintegration with time. For further information write to the Keystone Asphalt Products Co., 43 East Ohio Street, Chicago, Ill.

"The Story of Ziebarth Construction" should interest you. Replete with photographs, it is a story by Fritz Ziebarth, the man whose company has built the 237 miles of high voltage transmission from Boulder Dam to the five Aqueduct Pumping Plants. This is but one phase of the story, which includes high tension lines from Bonneville and Grand Coulee Dams, power lines to the world's largest magnesium plant, Basic Magnesium, in the blistering Southern Nevada Desert, and the "bridging" of mountainous Lake Chelan in Washington.

Surprising as it may seem, this company, which has specialized in transmission line work has also built sewage treatment plants, pumping plants, harbor facilities and water supply towers. Proud of their slogan of "Get the job done—fast!", the company is proud, too, of their services to the United States Army Engineers, Bureau of Reclamation, Defense Plant Corporation, and many others.

Ziebarth Construction has done every type of "earth moving," the basic function of the heavy construction industry. This booklet may give you an insight into the requirements you should demand when you select a contractor to do a heavy construction job. Certainly you will find an interesting story if you write for a free copy to Fritz Ziebarth, 861 W. Esther St., Long Beach, Cal.

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Wherever SEWAGE GAS IS UTILIZED!

Protect your valuable equipment against sulphur damage. Stop sticky valves!! Keep your oil free of acid sludge caused by sulphur in your gas. The Connelly method of gas purification is eliminating this costly damage in leading plants all over the country—and it can do the same for you. Let Connelly engineers show you how it can be done—easily—quickly—economically.

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Connelly Manometer (U-Gauge). For portable or stationary use. Unbreakable plastic tubes. Accurate—dependable. Wide range of sizes.

Connelly H₂S Tester. An accurate and convenient instrument giving permanent record for future reference.

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Style 705 MERCURY FILTER CLOTH

Designed for Sewage and Disposal Plants

This all wool Mercury Filter Cloth is made from specially processed wool. Our 30 years of experience have proven that this wool withstands deterioration better and longer than other filter fabrics. Send us dimension of fabric you now use—we will be pleased to submit samples, price and full particulars.

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When Hell Broke Loose In Tunis

Layne Wells and Pumps were in the thick of things when hell broke loose to crush the Axis troops in Tunis. Only the military authorities could tell of how they came through, but if they were not destroyed by the enemy—or our own terrific fire power, those sturdily built, tough and long lasting Wells and Pumps are still in there pitching—producing millions of gallons of water daily.

The Wells and Pumps in Tunis—and those throughout the African War Zone—Dakar, Algiers, Casablanca, Sousse, Kairouan, etc., were installed by Layne Engineers for peacetime duty, but they had the guts that made them give outstanding war-time service.

Whether for peace or war, Layne Well Water Systems and Pumps stand alone in skilful design, proven superior features, long life and highest efficiency. They are, according to the Layne slogan "Better Built for Better Service."

In the post-war era your Layne Wells and Pumps will be still higher in efficiency—longer in life and of further improved design. In the meantime, the Layne Organization is endeavoring to keep all industrial and municipal installations in repair and operating at peak efficiency. For literature, address, Layne & Bowler, Inc. General Offices, Memphis, Tenn.

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LAYNE

WELL WATER SYSTEMS

DEEP WELL PUMPS

Builders of Well Water Systems for Every Municipal and Industrial Need

Emergency Wood Pipe—Is featured in the May-June issue of "The Highway Magazine" (Armco Drainage Products Association) which carries a two page spread of pictures and captions showing installations in which "Emergency Wood Pipe Saves Steel and Transportation." Not only is the pipe used in culverts under roadways and railroad spurs but at at least one Army Air Base in Utah an installation carries the effluent from a sewage disposal plant. To avoid leakage or infiltration, special precautions were taken to make this 18-inch pipe reasonably watertight.

This war-borne product, which we understand has been used in several sewerage systems, weighs from 1/5 to 1/10 as much as alternate pipe. It is believed that its use will save approximately 9,000 tons of steel this year and also conserve much trucking and railroad space. The pipe is obtainable in 18 to 78-inch diameters with sections up to 58 ft. long. For additional information consult "ARMCO," Middletown, Ohio.

Vacuum Flotation is a new process for sewage and industrial waste treatment described by A. J. Fischer in a reprint from *Engineering News-Record*, released by the Dorr Co. The unit in which this process is accomplished is known as the Vacuator and the flotation action is accomplished in three steps: Aeration, De-aeration, and Use of the Vacuator.

The principle of the process is to rapidly remove small bubbles of air or other entrained gases which attach themselves to small non-settling and non-floating particles in sewage. With the rise of these small bubbles to the surface the amount of material that may be skimmed off is increased appreciably. The purpose of such a process is obviously to remove a greater percentage of suspended particles than will normally be removed by sedimentation or normal flotation in settling tanks.

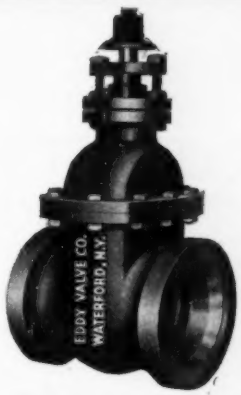
In order to obtain maximum flotation it is usually necessary to preaerate the sewage and deaerate to remove the larger bubbles. The vacuator is similar in design to a clarifier except that it is closed to permit establishment of a vacuum and is small to prevent deposition of particles except those of coarse size.

The article describes laboratory

EDDY

FIRE HYDRANTS AND VALVES—

WATER WORKS EQUIPMENT



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For Fire Protection Service

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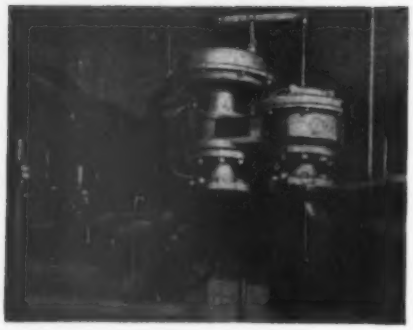

P. F. T. Flame Traps protect the sewage treatment plants of over 200 war projects

In camps and armament plants throughout the nation, the fire and explosion hazards created by sewage gas at the disposal plants are eliminated by P.F.T. Flame Traps, P.F.T. Boiler Room Equipment is preferred.

Write for Bulletin No. 121-A describing P.F.T. Flame Traps, Pressure Relief Valves, Waste Gas Burners, Condensate Drip Traps, Pressure Gages and other boiler room accessories which assure sage operation of digested sewage sludge treatment plants.

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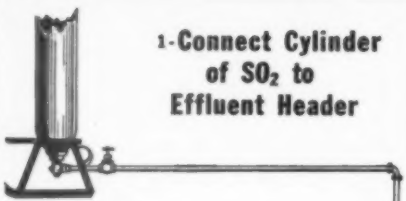
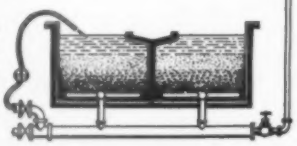
New York Charlotte, N. C.

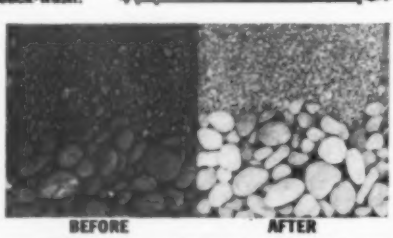
HOW TO CLEAN SAND FILTERS in 24 HOURS

1-Connect Cylinder of SO_2 to Effluent Header



2-Recirculate sulphurous acid solution for 16 to 24 hours and back-wash.





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3-RESULT: Clear, white sand and gravel; time, labor and money saved.

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WEST NORFOLK, VIRGINIA

tests and the operation of a pilot plant in Los Angeles as well as several plant installations now functioning on cannery wastes, sewage, and rubber wastes. Oil refinery wastes have also been treated experimentally in the unit. For additional information write the Dorr Co., Inc., New York, N. Y.

Survey of Water Technology is a ten page booklet reviewing the progress made during 1942 in industrial water condition. Reprinted from *Paper Trade Journal* and released by W. H. and L. D. Betz, Survey of Water Technology is divided into ten subjects: A—Water in the War Production Program, B—Water the raw material, C—Process water for industry, D—Water Treatment, E—Water Analysis, F—Corrosion, G—Boiler Feedwater and Cooling Water, H—Bacteriology and Biochemistry of Water, I—Equipment, J—Recent Books on Water and Related Subjects. Under each of these ten headings appears a brief description and listing of the important articles written on the subject during the past year. In all 266 references are included, of which 65 are books.

Survey of Water Technology was prepared by Dr. Lewis B. Miller, a member of the Consulting Division of W. H. & L. D. Betz, and presented at the annual meeting of the Technical Association of the Pulp and Paper Industry. Designated as Betz Technical Paper No. 86, this booklet will be furnished free on request to W. H. & L. D. Betz, Consulting Chemical Engineers, Philadelphia 24, Pa.

Deaeration of Boiler Feed and Process Water is the subject of a comprehensive 36 page treatment by Cochrane Corp. of Philadelphia of tray-type deaerators—atomizing deaerators — deaerating hot water generators and—cold water deaerators. Sections are devoted to: flow-diagrams including photographs of installations described; corrosion control; pH control; metering deaerating equipment with V-Notch recorder and electrical systems for recording flow at a distance, when the recorder is located on a centralized panel board; cross-section photographs and line diagrams in color to clarify the operation of the Cochrane deaerators; as well as illustrations of various designs that are constructed to meet space limitations and operating re-

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FIBREX — The sanitary paper packing that is used like braided jute. Free from bacteria — treated with a water repellent —put up in 60 pound reels. 70 pounds of Fibrex takes the place of 100 pounds of braided jute.

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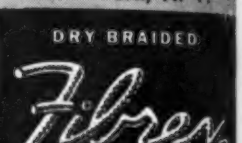

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- High capacity
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FOR COAGULATION AID Insures a clearer effluent and increases filter capacity.

FOR CORROSION PREVENTATIVE Eliminates "red water" and protects water mains and service pipes.

Ask for complete information. No obligation.

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quirements; and accessories equipment. A copy of this publication (No. 3005) will be sent on request to Cochrane Corporation, Philadelphia, Pa.

Lignum-Vitae is presented in booklet form by the Lignum-Vitae Products Corp. This report tells the story of how Lignum-Vitae is substituting for critical materials, plastic and metal, and how it is being used for mechanical and industrial purposes helping industry in All-Out-For-Victory effort.

One page of the report is devoted to facts about Lignum-Vitae which is a very hard resinous wood from the Tropics. It is not to be confused with ordinary hardwoods of commerce, as it is the hardest, heaviest, and closest grained wood known, with a density almost equal to iron, weighing about 83 lbs. per cubic foot, and having a specific gravity of 1.3. The great density and homogeneity of Lignum-Vitae make it capable of withstanding conservatively, a working pressure of 2,000 lbs. per square inch, with a Modulus of Rupture of 11,200 lbs. per square inch and a Maximum Crushing Strength of 10,480.

The high resin content of Lignum-Vitae, which runs about 30 per cent of its weight, consists of a natural gum, which combined with its pressure resisting quality, renders this wood admirably suited for an ever-increasing number of mechanical purposes where the introduction of lubrication is not practicable or at all times reliable. It is not recommended that Lignum-Vitae be used where the applied or frictional heat generated is over 150 deg. Fahrenheit unless operating in or coming in contact with water or some other liquid which acts as a coolant.

In the Chemical Field, it is valued because of its ability to resist many Mild Acids and Chemicals. In the Food and Process Industries it is useful because it is non-contaminating, as well as self-lubricating. Water acts as a preservative and a greatly added lubricant to Lignum-Vitae. Being non-ferrous, of course, it is rustless and its natural resin protects it when it comes in contact with corroded surfaces.

The extreme hardness of Lignum-Vitae does not render it unworkable by any means, but rather enhances its value to industry.

(Continued on Page 130)

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"RUSTOP" the Cathodic System Immediately and Permanently Stops Corrosion on Submerged Metals.

CLEANS OLD TANKS
KEEPS NEW TANKS CLEAN

Conserves Valuable and Vital Equipment —Economically.

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THE CATHODIC SYSTEM OF CORROSION PREVENTION

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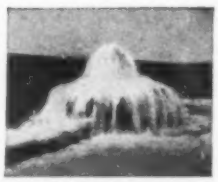

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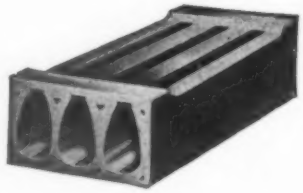

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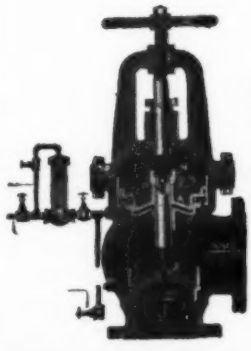

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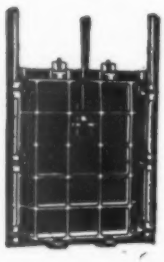

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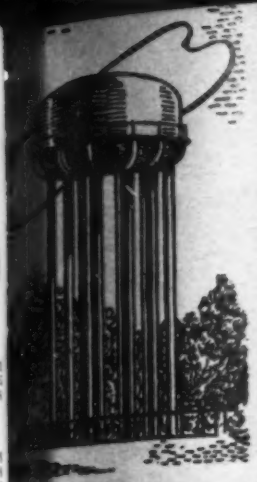

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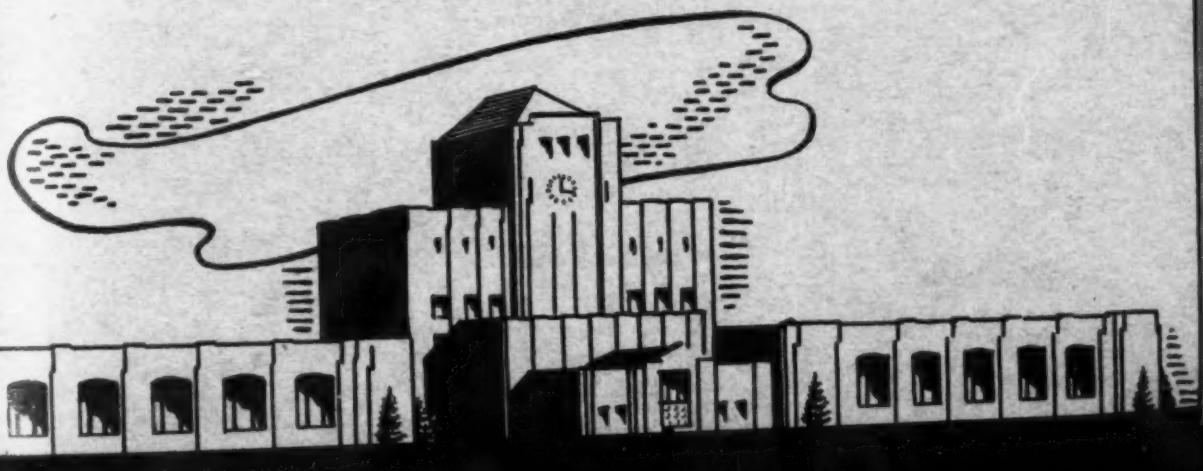

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Foreword

We take especial pride, as publishers, in presenting this volume—the Reference and Data Number of WATER WORKS AND SEWERAGE for 1943.

This section prepared by the Editor, with the aid of John C. Black, Managing Editor, and Dr. George E. Symons, Associate Editor, presents the equivalent of a data handbook for designing engineers, managers, and operators of water works and sewerage systems.

The information contained herein has been carefully selected from past issues of WATER WORKS AND SEWERAGE and other sources named in the text. In addition, considerable effort has been made to present the most economical and modern methods, and the latest tables and charts useful to water and sewage works operators and designers.

Even though supplied at no charge to subscribers, beyond the regular subscription fee, the same conscientious work has been put into the preparation of this Data Section as would be expected in a book devoted exclusively to the same type of material and published separately.

* * *

Note

All who become subscribers during the current year may have a copy of this special issue so long as the extra supply printed for the purpose lasts—and, at *no extra charge* above the regular subscription rate.

Old subscribers will note that a certain amount of material in this issue has appeared in earlier issues. With the constant influx of new subscribers in mind, useful tables and graphs and other basic data will be repeated each year, other material will be retained for use in alternate years, while some will be permanently replaced with new or revised material.

It is our endeavor not to repeat more than one-half of the material from year to year. It will, therefore, be necessary for each subscriber to possess issues of two consecutive years if he is to have available what may be termed a "complete" file of WATER WORKS AND SEWERAGE Reference and Data Material.

As a convenience to users an Index of the previous year's issue appears following the Index of material in this issue.

L. H. Enslow

Editor.

REFERENCE AND DATA INDEX—1943

For additional information on these subjects, see the 1942 index following.

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CLASSIFIED INDEX of PRODUCTS

Although this index is not published as a COMPLETE index of all materials and equipment used in the Water Works and Sewerage fields—it really is a very comprehensive list of products. It includes equipment and materials produced or marketed in this field by 189 manufacturers who have used WATER WORKS & SEWERAGE in advertising such products during 1942 and 1943. Of these 189 manufacturers you will find the advertisements of 146 in this issue.

ABRASIVES
Carborundum Co., Niagara Falls, N. Y.

ACID, SULPHURIC AND HYDROCHLORIC
General Chemical Co., 40 Rector St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ACTIVATED AND BLACK ALUM
Activated Alum Corp., Curtis Bay, Baltimore, Md.

ACTIVATED CARBON
Activated Alum Corp., Curtis Bay, Baltimore, Md.
American Norit Co., Jacksonville, Fla.
Cliffs Dow Chemical Co., Marquette, Michigan.
Darco Corporation, 60 E. 42nd St., New York City.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Industrial Chemical Sales Division, West Virginia Pulp & Paper Co., 230 Park Ave., New York City.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Stuart Brumley Corp., Baltimore, Md.

ACTIVATED SLUDGE EQUIPMENT
The American Well Works, Aurora, Illinois.
Carborundum Co., Niagara Falls, N. Y.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Vogt Mfg. Co., Louisville, Ky.

AERATION APPARATUS
Aluminum Co. of Amer., Gulf Bldg., Pittsburgh, Pa.
The American Well Works, Aurora, Ill.
Carborundum Co., Niagara Falls, N. Y.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

AGITATORS
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2336 Wolfram St., Chicago, Ill.
Dorr Co., Inc., 570 Lexington Ave., New York City.
The Elmco Corp., P. O. Box 300, Salt Lake City, Utah.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Mach. Co., Inc., 3409 E. 18th, Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Brumley Corp., Baltimore, Md.
Vogt Mfg. Co., Louisville, Ky.

AIR BLOWERS
(See Blowers, Air)

AIR COMPRESSORS
(See Compressors, Air)

ALLOY CAST IRON PIPE AND FITTINGS
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

ALTERNATORS, ELECTRIC
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Clark Controller Co., 1146 E. 152nd St., Cleveland, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.

ALUM, AMMONIA
Innis-Speiden & Co., 117 Liberty St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ALUM, BLACK
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Stuart Brumley Corp., Baltimore, Md.

ALUM (Filter), COMMERCIAL IRON-FREE
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Stuart Brumley Corp., Baltimore, Md.

AMMONIA, ANHYDROUS & AQUA
General Chemical Co., 40 Rector St., New York City.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Mathieson Alkali Wks., Inc., 60 E. 42nd St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

AMMONIATORS
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Omega Mach. Co., Inc., 3409 E. 18th, Kansas City, Mo.
Proportioneers, Inc., 9 Codding St., Providence, R. I. (Aqua)
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

ANALYTICAL WARE
Carborundum Co., Niagara Falls, N. Y.
Chemlab Specialties Co., 52 Alvarado Road, Berkeley, Calif.
Phipps & Bird, Inc., Sixth & Byrd Sts., Richmond, Va.

ANTHRAFILT
Anthracite Equipment Corp., 101 Park Ave., New York City.

AQUA AMMONIATORS
(See Ammoniators)

AQUAPHONES
Aqua Survey & Instrument Co., 1400 Marlowe Ave., Cincinnati, Ohio.
Northrop & Co., Inc., 50 Church St., N. Y., N. Y.

ASBESTOS-CEMENT PIPE
Johns-Manville Co., 22 E. 40th St., New York City.

ASH AND COAL HANDLING MACHINERY
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

AUTOMATIC FILTER AND SOFTENER CONTROLS
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., Philadelphia, Pa.

BACK FILLERS
Link-Belt Speeder Corp., 301 W. Pershing Rd., Chicago, Ill.

BAR SCREENS
The American Well Works, Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

BASE-EXCHANGE SILICATE
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th. Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

BASIN CLEANERS
Champion Corp., Hammond, Ind.
W. H. Stewart, P. O. 767, Syracuse, N. Y.

BEARINGS, ROLLER & BALL
Chain Belt Co., Milwaukee, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 519 N. Holmes Ave., Indianapolis, Ind.

BINS, STORAGE
Chain Belt Co., Milwaukee, Wis.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. P. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
National Fireproofing Corp., 202 E. Ohio St., N. S., Pittsburgh, Pa.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Portland Cement Association, 33 W. Grand Ave., Chicago, Ill.

BITUMINOUS COATINGS AND LININGS
(See also Cement Linings)
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.

BLACK ALUM
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Stuart Brumley Corp., Baltimore, Md.

BLEACHING POWDER
Hood Chemical Co., 450 W. 31st St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
O. S. Tyson & Co., Inc., 230 Park Ave., New York, New York.

BLOWERS, AIR (Centrifugal and Rotary)
Allen-Billmyre Corp., 449 Fayette Ave., Mamaroneck, N. Y.
De Laval Steam Turbine Co., Trenton, N. J.
Roots-Connersville Blower Corp., Connersville, Ind.

BLOWERS (Gasoline Engine Driven Portable)
Homelite Corporation, Port Chester, N. Y.

BOILER BLOWOFF APPARATUS
Permutit Co., 330 W. 42nd St., New York City.

BOILER FEED PUMP CONTROL
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

BOILER FEEDWATER TREATMENT
The American Well Works, Aurora, Ill.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Everson Mfg. Co., 214 W. Huron, Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Penn.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.
Worthington Pump & Machinery Corp., Harrison, New Jersey.
Zeolite Chemical Co., 140 Cedar St., New York City.

BOILER FURNACE, BRICK
Carborundum Co., Niagara Falls, N. Y.

BOILER PLANT ACCESSORIES
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Photoswitch, Inc., 21 Chestnut St., Cambridge, Mass.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

BOILER WATER & BOILER FEEDWATER CONTROL EQPT.
The Hagan Corp., Pittsburgh, Pa.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.

BOILERS, GAS
American Radiator & Standard Sanitary Corp., Bessemer Bldg., Pittsburgh, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

BOILER WATER PURIFICATION APPARATUS
The American Well Works, Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Everson Mfg. Co., 214 W. Huron, Chicago, Ill.
Graver Tank & Mfg. Corp., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 301 W. Pershing Rd., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 3409 E. 18th, Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.
Worthington Pump & Machinery Corp., Harrison, New Jersey.

BOXES, VALVES AND METERS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

BRAKES, MAGNETIC, MECHANICAL, HYDRAULIC
The Clark Controller Co., 1146 East 152nd St., Cleveland, Ohio.

BRASS GOODS
(See also Pipe, Brass.)
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

BREECHINGS, STEEL
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

BUCKETS, SEWER
Champion Corp., Hammond, Ind.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.

BUFFER SOLUTIONS & MIXTURES
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.

CALCIUM HYPOCHLORITE
(See also Bleaching Powder)
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Hood Chemical Co., 450 W. 31st St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

CALGON (See Corrosion Suppression and Water Stabilization)

CALKING MACHINES & TOOLS
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Schramm, Inc., West Chester, Pa.

CARBON-ACTIVATED
(See Activated Carbon.)

CARBONATORS (Recarbonation).
Carborundum Co., Niagara Falls, N. Y.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

CAR SPOTTERS & HAULAGE SYSTEMS
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2410 W. 18th St., Chicago, Ill.

CASTINGS, IRON, STEEL, ALLOY STEEL, ETC.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
The Central Foundry Co., 386 Fourth Ave., New York, N. Y.
Chain Belt Co., Milwaukee, Wis.
Climax Engineering Co., Clinton, Iowa.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
The Elmco Corp., P. O. Box 309, Salt Lake City, Utah.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
M & H Valve & Fittings Co., Anniston, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

CAST IRON PIPE
(See Pipe.)

CATCH BASIN INLET
Northrop & Co., Inc., 50 Church St., New York City.

CATCH BASINS, CORRUGATED IRON
American Rolling Mill Co., Middletown, Ohio.
Armco Drainage Products Assn., Middletown, Ohio.

CATHODIC PROTECTIVE PROCESS
Electro Rust-Proofing Co., 1026 Wayne Ave., Dayton, Ohio.
Rusta Restor Corp., 1480 W. State St., Fremont, Ohio.

CAULKING
Standard Dry Wall Products, Inc., New Eagle, Pa.

CAUSTIC SODA
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Hood Chemical Co., 450 W. 31st St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
Solvay Sales Corp., 40 Rector St., New York City.
O. S. Tyson & Co., Inc., 230 Park Ave., New York, New York.

CEMENT
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

CEMENT, ASBESTOS PIPE
Johns-Manville, 22 E. 40th St., New York City.

CEMENT PIPE
(See Pipe, Cement; Pipe, Concrete.)

CEMENT LINED PIPE
(See Pipe.)

CEMENT LINING OF PIPE
Cement Lined Pipe Co., Lynn, Mass.
Centriline Corp., 140 Cedar St., New York City.
Tate Pipe Linings, Inc., Andover, Mass.

CEMENTS, ACID PROOF
Atlas Mineral Prod. Co., Mertztown, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.

CEMENTS, REFRACTORY
Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St. New York City.

CEMENTS, SEWER PIPE
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.

CEMENTS, WATER MAINS
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Girard Trust Bldg., Philadelphia, Pa.

CHAINS (Elevating, Conveying & Power Transmission)
Chain Belt Co., Milwaukee, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

CHEMICAL CONVEYING EQUIPMENT
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

CHEMICAL FEEDING & PROPORTIONING EQUIPMENT
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 3409 E. 18th, Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., Sixth & Byrd, Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

CHEMICALS FOR WATER PURIFICATION
Activated Alum Corp., Curtis Bay, Baltimore, Md.
American Colloid Co., 363 W. Superior St., Chicago, Ill.
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Darco Corp., 60 E. 42nd St., New York City.
Diamond Alkali Co., Pittsburgh, Pa.
The Dow Chem. Co., Great Western Div., 310 Sansome St., San Francisco, Calif.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Industrial Chemical Sales Div West Virginia Pulp & Paper Co., 230 Park Ave., New York.
Innis-Speiden & Co., 117 Liberty St., New York City.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Mathieson Alkali Works, Inc., 60 E. 42nd St., New York.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
National Lime Assn., 927 Fifteenth St. N. W. Washington, D. C.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Reilly Tar Chem. Corp., Merchants Bank Bldg., Indianapolis, Ind.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Solvay Sales Corp., 40 Rector St., New York.
Standard Silicate Div., Diamond Alkali Co., Pittsburgh, Pa.
Stuart Brumley Corp., Baltimore, Md.
Tamms Silica Co., 228 N. LaSalle St., Chicago, Ill.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.
O. S. Tyson & Co., Inc., 230 Park Ave., New York, New York.
Virginia Smelting Co., West Norfolk, Va.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

CHEMISTS AND ENGINEERS
(See Directory of Experts, pages 132-133)

CHLORIDE OF LIME (Chlorinated Lime)
Hood Chemical Co., 450 W. 31st St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.

CHLORINATORS
(See also Hypochlorinators.)
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 3409 E. 18th, Kansas City, Missouri.
Phipps & Bird, Inc., Sixth & Byrd, St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

CHLORINE, LIQUID
Diamond Alkali Co., Pittsburgh, Pa.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.

Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
Solvay Sales Corp., 40 Rector St., New York.
O. S. Tyson & Co., Inc., 230 Park Ave., New York, New York.
Wallace & Tiernan, Inc., Newark, N. J.

CHLORINE CONTROL EQUIPMENT
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Omega Machine Co., 3409 E. 18th, Kansas City, Missouri.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

CHUTES, COAL, ETC.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Jeffrey Mfg. Co., Columbus, Ohio.
Link Belt Co., 300 W. Pershing Rd., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

CLAMPS AND SLEEVES, PIPE
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Carson-Cadillac Corp., Birmingham, Ala.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

CLAMPS, BELL JOINT
Carson-Cadillac Corp., Birmingham, Ala.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

CLAMPS, PIPE REPAIR
Carson-Cadillac Corp., Birmingham, Ala.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Northrop & Co., Inc., 50 Church St., New York City.

CLARIFIERS, SEWERAGE AND WATER
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 332 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Fritz Ziebarth, 820 W. Esther St., Long Beach, Calif.

CLEANING SEWER MAINS
Champion Corp., Hammond, Ind.
Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.

CLEANING WATER MAINS
Flexible Underground Pipe Cleaning Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 50 Church St., New York City.
Stuart Brumley Corp., Baltimore, Md.

COAGULANTS & COAGULATION CONTROL CHEMICALS
Activated Alum Corp., Curtis Bay, Baltimore, Md.
American Colloid Co., 363 W. Superior St., Chicago, Ill.
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Graver Tank & Mfg. Co., East Chicago, Indiana.
Innis-Speiden & Co., 117 Liberty St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York City.
Philadelphia Quartz Co., 124 S. Third St., Philadelphia, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Stuart Brumley Corp., Baltimore, Md.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

COAL & ASHES HANDLING MACHINERY
(See Ash & Coal Handling Machy.)

COATINGS, ACID & ALKALI-PROOF FOR CONCRETE, STEEL AND WOOD
Atlas Mineral Products Co., Mertztown, Pa.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Philadelphia Quartz Co., Philadelphia, Pa.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

COATINGS AND LININGS
(See Bituminous Coatings and Linings.)

COCKS, CURB, METER, CORPORATION, ETC.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Merco Nordstrom Valve Co., Lexington Ave., Pittsburgh, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

COLLESTORS (Sludge)
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Fritz Ziebarth, 820 W. Esther St., Long Beach, Calif.

COMBUSTION INDICATORS AND RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Fischer & Porter Co., Hatboro, Pa.
Photoswitch, Inc., 21 Chestnut St., Cambridge, Mass.
Permutit Co., 330 W. 42nd St., New York City.

COMMINUTORS
(See Grinders also)
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

COMPARATORS
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

COMPOUNDS, SEWER JOINT
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Reilly Tar & Chem. Corp., Merchants Bank Bldg., Indianapolis, Ind.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.

COMPRESSORS, AIR
De Laval Steam Turbine Co., Trenton, N. J.
Gardner-Denver Co., Quincy, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Roots-Connersville Blower Corp., Connersville, Ind.
Schramm, Inc., West Chester, Pa.
Sullivan Machinery Co., Michigan City, Indiana.
Worthington Pump & Machinery Corp., Harrison, New Jersey.

CONCRETE
Portland Cement Association, 33 W. Grand Ave., Chicago, Ill.

CONCRETE BREAKERS
Gardner-Denver Co., Quincy, Ill.
Schramm, Inc., West Chester, Pa.
Sullivan Machinery Co., Michigan City, Indiana.

CONCRETE HARDENER
Connelly Iron Sponge and Governor Co., 3154 So. California Ave. Chicago, Ill.
Diamond Alkali Co., Pittsburgh, Pa.
Philadelphia Quarts Co., 124 S. Third St., Philadelphia, Pa.
Sika, Inc., Passaic, N. J.
Standard Silicate Div., Diamond Alkali Co., Pittsburgh, Pa.

CONCRETE MIXERS
Chain Belt Co., Milwaukee, Wis.

CONCRETE PIPE
(See Pipe, Concrete.)

CONDENSERS (Steam)
Amer. Cast Iron Pipe Co., Birmingham, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
Worthington Pump & Machy. Corp., Harrison, N. J.

CONTROLLERS, AUTOMATIC, ELECTRIC
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Fischer & Porter Co., Hatboro, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

CONTROLLERS, FLOW, LEVEL, PRESSURE, TEMPERATURE
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Fischer & Porter Co., Hatboro, Pa.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York, N. Y.
Photoswitch, Inc., 21 Chestnut St., Cambridge, Mass.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

CONVEYORS AND CONVEYING EQUIPMENT
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Mfg. Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

COOLING TOWERS
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.

COPPER, BRASS, BRONZE
American Brass Co., Waterbury, Conn.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.

COPPERAS (Sulphate of Iron)
Innis-Speiden & Co., 117 Liberty St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.

COPPER SULPHATE
General Chemical Co., 40 Rector St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.

COPPER TUBE, FLEXIBLE
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.

CORROSION SUPPRESSION
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio.
Rusta Restor Corp., 1480 W. State St., Fremont, Ohio.

COUPLINGS & CONNECTIONS, PIPE
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
National Tube Co., Frick Bldg., Pittsburgh, Pa.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

COUPLINGS, FLEXIBLE
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Chain Belt Co., Milwaukee, Wis.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Dresser Mfg. Co., Bradford, Pa.
Jeffrey Mfg. Co., Columbus, Ohio.
Link Belt Co., 220 S. Belmont Ave., Indianapolis, Ind.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

COVERS, HANDHOLE, MANHOLE, SAMPLING
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
Northrop & Co., Inc., 50 Church St., New York City.
United Concrete Form Products Co., 5243 W. 25th Pl., Chicago, Ill.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

CRANES & HOISTS
Link-Belt Speeder Corp., 301 W. Pershing Rd., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.

CULVERT CLEANERS
Champion Corp., Hammond, Ind.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.

CULVERTS
American Cast Iron Pipe Co., Birmingham, Ala.
American Rolling Mill Co., Middletown, Ohio.
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
The Central Foundry Co., 386 Fourth Ave., New York, N. Y.
Clow and Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City (Asbestos-Cement).
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J. (Cast Iron)
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., Philadelphia, Pa.

CURB BOXES
Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.

DECHLORINATING EQUIPMENT AND CHEMICALS
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.

Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Virginia Smelting Co., West Norfolk, Va.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

DEMOLITION TOOLS
Gardner-Denver Co., Quincy, Ill.
Schramm, Inc., West Chester, Pa.
Sullivan Machinery Co., Michigan City, Indiana.

DIAPHRAGM, PUMP
Ralph B. Carter Co., 53 Park Pl., New York City.
The Deming Company, Salem, Ohio.
Dorr Co., 570 Lexington Ave., New York City.
Edson Corp., 49 D St., South Boston, Mass.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

DIFFUSERS—PLATES & TUBES
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

DIGESTERS EQUIPMENT (Sludge)
Ralph B. Carter Co., 53 Park Pl., New York City.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

DISTRIBUTORS (Filter)
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

DRAINS, STORM
American Rolling Mill Co., Middletown, Ohio.
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., Philadelphia, Pa.

DRIVES, CHAIN
Chain Belt Co., Milwaukee, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

DRY CHEMICAL FEEDERS
(See Chemical Feeding Equipment)

DRYERS, ROTARY
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

ELECTRICALLY OPERATED GATE VALVES
Crane Co., 836 S. Michigan Ave., Chicago.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

ELEVATING AND CONVEYING EQUIPMENT
(See Conveyors & Conveying Equipment.)

ENGINEERS AND CHEMISTS
(See Directory of Experts, pages 132-133)

ENGINEER'S REPRODUCTION SERVICE
Lithoprint Co. of N. Y., 145 Hudson St., New York, N. Y.

ENGINE GENERATING SETS
Climax Engineering Co., Clinton, Iowa.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Homelite Corp., Port Chester, N. Y. (Gasoline Engine Driven and Portable.)
Northrop & Co., Inc., 50 Church St., New York City (Gasoline Driven Portable.)
Worthington Pump & Machy. Corp., Harrison, N. J.

ENGINES, DIESEL
Climax Engineering Co., Clinton, Iowa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Schramm, Inc., West Chester, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

ENGINES (Gas & Gasoline)
Climax Engineering Co., Clinton, Iowa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

EXPANSION JOINTS—PIPE
(See Joints—Expansion, Pipe)

EXHAUSTERS, AIR
(See Vacuum Pump)

FEED, CHEMICAL
(See Chemical Feeding Equipment.)

FEED WATER FILTERS
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Worthington Pump & Machinery Corp., Harrison, N. J.

FEED WATER HEATERS
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Worthington Pump & Machy. Corp., Harrison, N. J.

FEED WATER TREATMENT
(See Boiler Feed Water Treatment)

FERRIC CHLORIDE
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
General Chemical Co., 40 Rector St., New York City.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Innis, Speiden & Co., 117 Liberty St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa. (Liquid)
O. S. Tyson & Co., Inc., 230 Park Ave., New York, New York.
Wallace & Tiernan Co., Inc., Newark, N. J.

FERRIC CHLORIDE FEEDERS
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Omega Machine Co., Inc., 3400 E. 18th, Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., Sixth & Byrd, Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

FERRIC SULFATE
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Tennessee Corp., 621 Grant Bldg. Atlanta, Ga.

FERROUS SULPHATE
General Chemical Co., 40 Rector St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.

FILTER-AIDS
Anthracite Eqpt. Corp., 101 Park Ave., New York City.
Johns-Manville, 22 E. 40th St., New York City. (Celite.)
L. A. Salomon & Bro., 216 Pearl St., New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Stuart Brumley Corp., Baltimore, Md.

FILTER CLEANING PROCESS
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Brumley Corp., Baltimore, Md.
Virginia Smelting Co., West Norfolk, Va.

FILTER CLOTH
Mercury Technical Cloth & Felt Corp., 1265 Broadway, New York City.

FILTERING EQUIPMENT
The American Well Works, Aurora, Ill.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chain Belt Co., Milwaukee, Wis.
R. D. Cole Mfg. Co., Newnan, Ga.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Laughlin Equipment Corp., 270 Madison Ave., New York City.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Oliver United Filter, Inc., New York City.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Stuart Brumley Corp., Baltimore, Md.
Underpinning & Foundation Co., Inc., 155 E. 44th St., New York City (For Sewage)
Worthington Pump & Machinery Corp., Harrison, N. J.

FILTER PLATES AND TUBES
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2336 Wolfram St., Chicago, Ill.

FILTER RATE CONTROLLERS & GAGES
(See Rate Controllers.)

FILTER & WATER SOFTENING PLANTS (Complete)
The American Well Works, Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
R. D. Cole Mfg. Co., Newnan, Ga.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Neville Island P. O., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence. R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Brumley Corp., Baltimore, Md.
Worthington Pump & Machinery Corp., Harrison, N. J.
Zeolite Chemical Co., 140 Cedar St., New York City.
Fritz Ziebarth, 820 W. Esther St., Long Beach, Calif.

FILTER UNDERDRAINS (Pier & Plates)
Armco Drainage Products Assn., Middletown, Ohio.
Carborundum Co., Niagara Falls, N. Y.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams, Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Brumley Corp., Baltimore, Md.

FILTER UNDERDRAINS (Trickling, Sewage)
National Fireproong Corp., 202 East Ohio St., N. S., Pittsburgh, Pa.

FILTER WASH CONTROL
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

FILTER SAND
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Laughlin Equipment Corp., 270 Madison Ave., New York City.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Tamms Silica Co., 228-WS N. La Salle St., Chicago, Ill.
Zeolite Chemical Co., 140 Cedar St., New York City.

FITTINGS, PIPE, SOLDER TYPE
American Brass Co., Waterbury, Conn.
American Smelting and Refining Co., 120 Broadway, N. Y. C.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.

FITTINGS, TEES, ELLS, ETC.
American Brass Co., Waterbury, Conn.
American Cast Iron Pipe Co., Birmingham, Ala.
American Smelting and Refining Co., 120 Broadway, N. Y. C.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Carson-Cadillac Corp., Birmingham, Ala.
The Central Foundry Co., 386 Fourth Ave., New York, N. Y.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Hays Mfg. Co., Erie, Pa.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

FLASH MIXING EQUIPMENT
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Carborundum Co., Niagara Falls, N. Y.

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 3409 East 18th St., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.

FLEXIBLE JOINTS
(See Joints, Flexible Pipe.)

FLOATING COVERS
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

FLOCCULATING EQUIPMENT
The American Well Works, Aurora, Ill.
Carborundum Co., Niagara Falls, N. Y.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., Inc., 3409 E. 18th St., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

FLOOR STANDS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa (Manually and Electrically Operated)
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Merco Nordstrom Valve Co., Lexington Ave., Pittsburgh, Pa.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

FLOW METERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Fischer & Porter Co., Hatboro, Pa.
Northrop & Co., Inc., 50 Church St., New York City.
Roots-Connersville Blower Corp., Connersville, Ind.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

FLOW RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Fischer & Porter Co., Hatboro, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

FLOW REGULATORS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

FLUMES, IRON & STEEL
Armco Drainage Products Assn., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. P. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Rodney Hunt Machine Co., Orange, Mass.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

FOOT VALVE WITH STRAINER
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Edson Corp., 49 D St., So. Boston, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

FORMS & GASKETS FOR PIPE JOINTS
Johns-Manville, 22 E. 40th St., New York City.
L. A. Weston, Adams, Mass.

FURNACES, MELTING, POURING LADLES, POTS, ETC.
Atlas Mineral Products Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.

GARBAGE DISPOSAL APPARATUS
Carborundum Co., Perth Amboy, N. J.
Chain Belt Co., Milwaukee, Wis.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Nichols Engr. & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Underpinning & Foundation Co., 155 E. 44th St., New York City.

GAS DIFFUSERS
The American Well Works, Aurora, Ill.
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2336 Wolfram St., Chicago Ill.
Dorr Co., 570 Lexington Ave., New York City.
Vogt Mfg. Co., Louisville, Ky.

GAS HOLDERS
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago Ill.
R. P. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc. East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

GAS PUMPS
(See Pumps, Gas)

GAS PURIFICATION
Connelly Iron Sponge and Governor Co., 3154 So. California Ave., Chicago, Ill.

GAS REGULATORS
(Pressure & Flow)
(See Regulators—Water & Gas)

GATES, SHEAR
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

GATES, SLUICE
American Rolling Mill Co., Middletown, Ohio.
Armco Drainage Products Assn., Middletown, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.

GATE VALVES
(See Valves, Gate.)

GAUGES (Liquid Level, Pressure Recording)
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City (Pressure)
Photoswitch, Inc., 21 Chestnut St., Cambridge, Mass.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.

GEARS, SPEED REDUCING
De Laval Steam Turbine Co., Trenton, N. J.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

GENERATOR SETS, GAS & DIESEL ENGINES
(See Engine Generating Sets)

GOOSENECKS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.

GREEN SAND (Zeolite)
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Zeolite Chemical Co., 140 Cedar St., New York City.

GRINDERS
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.

GRIT CHAMBER EQUIPMENT
The American Well Works, Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

HOSE, STEAM, AIR, WATER, SUCTION
American Brass Co., Waterbury, Conn.
Edson Corp., 49 D St., So. Boston, Mass.
Gardner-Denver Co., Quincy, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Schramm, Inc., West Chester, Pa.
Sullivan Machinery Co., Michigan City, Indiana.

HYDRANT PUMPS
(See Pumps, Hydrant.)

HYDRANTS (Fire)
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Decatur, Ill.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

HYDRAULICALLY OPERATED GATE VALVES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

HYDROGEN ION EQUIPMENT
(See pH Test Equipment.)

HYPO-CHLORINATORS
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

HYPOCHLORITES (High Test)
(See Calcium Hypochlorite)

INCINERATORS
Dorr Co., Inc., 570 Lexington Ave., New York City.
Morse Boulger Destructor Co., 216 East 45th St., New York City.
Nichols Engr. & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Underpinning & Foundation Co., 155 E. 44th St., New York City.

INDICATOR POSTS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

INDICATORS, LARGE DIAL, ILLUMINATED
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, O.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

INSULATION
Carborundum Co., Perth Amboy, N. J.
Ford Meter Box Co., Wabash, Ind. (Water Meter).
Johns-Manville, 22 E. 40th St., New York City.

IRON SULPHATE
Innis, Speiden & Co., 117 Liberty St., New York City.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.

JOINTING COMPOUND
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.
Servicised Products Corp., 6051 West 65th St., Chicago, Ill.

JOINTS, EXPANSION—PIPE
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.

Central Foundry Co., 386 Fourth Ave., N. Y., N. Y.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
Lock Joint Pipe Co., Ampere, N. J.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

JOINTS, FILLER
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.

JOINTS, FLEXIBLE PIPE
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Hays Mfg. Co., Erie, Pa.
Lock Joint Pipe Co., Ampere, N. J.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

JOINTS (Mechanical, Flexible)
American Cast Iron Pipe Co., Birmingham, Ala.
Carson-Cadillac Corp., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Hays Mfg. Co., Erie, Pa.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

JUTE, BRAIDED AND TWISTED
Atlas Mineral Prod. Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hydraulic Development Corp., 50 Church St., New York City.
Johns-Manville, 22 E. 40th St., New York City.

LABORATORY APPARATUS
Carborundum Co., Niagara Falls, N. Y.
Chemlab Specialties Co., 52 Alvarado Road, Berkeley, Calif.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
E. Leitz, 730 Fifth Ave., New York City.
Omega Mach. Co., Inc., 3409 E. 18th, Kansas City, Mo.
Phipps & Bird, Inc., Sixth & Byrd, Richmond, Va.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

LEAK LOCATING INSTRUMENTS
(See Water Leak Locating Instruments)

LIQUID CHLORINE
(See Chlorine, Liquid.)

LIME
National Lime Assn., 927 Fifteenth St. N. W. Washington, D. C.

LUBRICATING OILS & GREASES
Macmillan Petroleum Corp., 530 W. Sixth St., Los Angeles, Calif.

MANOMETERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Connelly Iron Sponge and Governor Co., 3154 S. California Ave., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

MAP REPRODUCTIONS
Lithoprint Co. of N. Y., 145 Hudson St., New York City.

METER ACCESSORIES, BOXES, HOUSING, ETC.
Badger Meter Co., Milwaukee, Wis.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METER COUPLINGS & YOKES
Badger Meter Mfg. Co., Milwaukee, Wis.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Neptune Meter Co., 50 West 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METERS, GAS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, O.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Roots-Connersville Blower Corp., Connersville, Ind.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

METERS, PITOT
Pitometer Co., 50 Church St., New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

METER TESTING EQUIPMENT
Badger Meter Mfg. Co., Milwaukee Wis.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
National Meter Division of Pittsburgh Equitable Meter Co., 4259 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Worthington - Gamon Meter Co., Newark, N. J.

METERS, VENTURI
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upham Sts., Philadelphia, Pa.

METERS, WATER & SEWAGE
Badger Meter Mfg. Co., Milwaukee, Wis.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
National Meter Division of Pittsburgh Equitable Meter Co., 4259 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Phoenix Meter Corp., Prince Bay, Staten Island, New York.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.
Worthington - Gamon Meter Co., Newark, N. J.

METER WASHERS
Mabbs Hydraulic Packing Co., 431 S. Dearborn St., Chicago, Ill.

MIXERS, CHEMICAL
The American Well Works, Aurora, Ill.
Carborundum Co., Niagara Falls, N. Y.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Mach. Co., Inc., 3409 E. 18th, Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

MIXERS, CONCRETE
(See Concrete Mixers)

MIXING EQUIPMENT
(Water & Sewage)
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., 1600 W. Bruce St., Milwaukee, Wis.
Chicago Pump Co., 2336 Wolfram St., Chicago, Ill.
Dorr Co., Inc., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.

MOTOR STARTERS
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

MOTORS, ELECTRIC
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.

NIPPLES, PIPE
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.

NOZZLES, FLOW
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chain Belt Co., Milwaukee, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

NOZZLES, SPRAY
Chain Belt Co., Milwaukee, Wis.
Grover Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Mueller Brass Co., Port Huron, Mich.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

ODOR CONTROL
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Industrial Chemical Sales Div., West Va. Pulp & Paper Co., 230 Park Ave., New York City.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Stuart Brumley Corp., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

ODOR & CARBON EVALUATION AIDS
American Norit Co., Jacksonville, Fla.
Darco Corp., 60 E. 42nd St., New York City.
Industrial Chemical Sales Div., West Va. Pulp & Paper Co., 230 Park Ave., New York City.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Stuart Brumley Corp., Baltimore, Md.

OPERATING TABLES
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

ORIFICES
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

PACKING
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hyde-ro Rings (Ralph H. Hyde), P. O. Box 1, Campbell, Calif.
Johns-Manville, 22 E. 40th St., New York City.
Northrop & Co., Inc., 50 Church St., New York City.

PACKING, RAWHIDE
Mabbs Hydraulic Packing Co., 431 S. Dearborn St., Chicago, Ill.

PAINT, ACID RESISTING
Atlas Mineral Prod. Co., Mertztown, Pa.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.
Stuart Brumley Corp., Baltimore, Md.
Tamms Silico Co., 228-WS N. LaSalle St., Chicago, Ill.

PENSTOCKS
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Rodney Hunt Machine Co., Orange, Mass.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

pH CONTROL FEEDERS
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

pH TEST EQUIPMENT
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
E. Leitz, Inc., 730 Fifth Ave., New York City.
Beckman Instruments Div., National Technical Laboratories, So. Pasadena, Calif.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

PIPE AND TANK COATINGS
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.
Stuart Brumley Corp., Baltimore, Md.

PIPE, ASBESTOS-CEMENT
Johns-Manville Co., 22 E. 40th St., New York City.

PIPE BENDING MACHINES
Hays Mfg. Co., Erie, Pa.

PIPE, BRASS AND COPPER
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Brass Co., Port Huron, Mich.

PIPE, CAST IRON
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 4th Ave., New York City.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE, CAST IRON (Service)
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., N. Y., N. Y.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

PIPE, CEMENT LINED
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Cement Lined Pipe Co., 93 Brookline St., Lynn, Mass.
Central Foundry Co., 386 Fourth Ave., New York City.
Centriline Corp., 140 Cedar St., New York City.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE, CEMENT LININGS
Cement Lined Pipe Co., 93 Brookline St., Lynn, Mass.
Centriline Corp., 140 Cedar St., New York City.
Tate Pipe Linings, Inc., 47 Haverhill St., Andover, Mass.

PIPE, CONCRETE, PRESSURE
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Association, 33 W. Grand Ave., Chicago, Ill.

PIPE, COPPER
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.

PIPE, CORRUGATED
American Rolling Mill Co., Middletown, Ohio.
Armco Drainage Products Assn., Middletown, Ohio.

PIPE, CULVERT
American Rolling Mill Co., Middletown, Ohio.
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago.
Central Foundry Co., 386 Fourth Ave., N. Y., N. Y.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE CUTTING MACHINES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

PIPE, DRILLS, JACKS AND PUSHERS
Northrop & Co., Inc., 50 Church St., New York City.

PIPE ENAMELS, PROTECTIVE—COAL TAR
General Paint Corp., 3001 Mayfield Rd., Cleveland, Ohio.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.

PIPE, FELT WRAPPING
General Paint Corp., 3001 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.

PIPE FITTINGS
American Cast Iron Pipe Co., Birmingham, Ala.
American Smelting and Refining Co., 120 Broadway, N. Y. C.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Carson-Cadillac Corp., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Clow and Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Hays Mfg. Co., Erie, Pa.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE—GALVANIZED, LIGHT-WEIGHT (Quick Coupling, Transportable for Conveying Water)
Champion Corp., Hammond, Ind.

PIPE JOINT COMPOUNDS
(See Jointing Compounds.)

PIPE JOINTS (Mechanical)
Carson-Cadillac Corp., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., N. Y., N. Y.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Hays Mfg. Co., Erie, Pa.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
L. A. Weston, Adams, Mass.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE JOINT TOOLS
Atlas Mineral Prod. Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

PIPE, LEAD LINED
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

PIPE LOCATORS
Aqua Survey & Instrument Co., 1409 Marlowe Ave., Cincinnati, Ohio.
Frank N. Blake, North Adams, Mass.
S. F. Ferguson, Douglas Hotel Bldg., Newark, N. J.
Northrop & Co., Inc., 50 Church St., New York City.

PIPE PUSHERS
Northrop & Co., Inc., 50 Church St., New York City.

PIPE, SEWER
American Cast Iron Pipe Co., Birmingham, Ala.
American Rolling Mill Co., Middletown, Ohio.
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Clow and Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill. (Reinforced Concrete)
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.
A. Wyckoff & Son Co., Elmira, N. Y.

PIPE, STEEL
American Rolling Mill Co., Middletown, Ohio.
Cement Lined Pipe Co., Lynn, Mass.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

PIPE, SUBAQUEOUS
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., N. Y., N. Y.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE TAPPING MACHINES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

PIPE TEST PLUGS
Northrop & Co., Inc., 50 Church St., New York City.

PIPE, WELDED STEEL
American Rolling Mill Co., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

PIPE, WRAPPING
General Paint Corp., 3001 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.

PITOT TUBES
Pitometer Company, 50 Church St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

PLUGS
Standard Dry Wall Products, Inc., New Eagle, Pa.

PNEUMATIC CONVEYORS FOR WATER AND SEWAGE TREATMENT
Dracco Corp., Cleveland, Ohio.

PNEUMATIC TOOLS
Schramm, Inc., Westchester, Pa.
Sullivan Mach. Co., Michigan City, Ind.

POROUS TUBES AND PLATES
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2336 Wolfram St., Chicago, Ill.

PRESSURE REGULATORS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Connelly Iron Sponge and Governor Co., 3154 S. California Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

PROPORTIONING EQUIPMENT (Chemical)
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., Sixth & Byrd, Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

PUMP MOTOR STARTERS
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

PUMP PRIMERS
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Roots-Connersville Blower Corp., Connersville, Ind.

PUMPS, ACID-HANDLING
Ralph B. Carter Co., 53 Park Place, New York City.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, BOILER FEED
The American Well Works, Aurora, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Economy Pump Inc., Hamilton, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Vogt Brothers Mfg. Co., Louisville, Ky.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, CELLAR DRAINER
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
The Deming Co., Salem, Ohio.
Economy Pumps, Inc., 1024 Weller Ave., Hamilton, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26 Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, CENTRIFUGAL
The American Well Works, Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Economy Pump Inc., Hamilton, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
Homelite Corp., Port Chester, N. Y.
Layne & Bowler, Inc., Memphis, Tenn.
Morris Machine Works, Baldwinsville, N. Y.
Northrop & Co., 50 Church St., New York City.

Peerless Pump Division Food Machinery Corp., 301 West Avenue 26 Los Angeles, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, CONDENSATION
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Economy Pump Inc., Hamilton, O.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26 Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, DEEP WELL
The American Well Works, Aurora, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
The Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S Michigan Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26 Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, DIAPHRAGM
Ralph B. Carter Co., 53 Park Place, New York City.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
The Deming Co., Salem, Ohio.
Dorr Co., 570 Lexington Ave., New York City.
Edson Corp., 49 D St., South Boston, Mass.
The Elmco Corp., P. O. Box 300, Salt Lake City, Utah.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

PUMPS, DRAINAGE
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Economy Pumps, Inc., 1024 Weller Ave., Hamilton, Ohio.
Fairbanks, Morse & Co., 600 S Michigan Ave., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
S. Morgan Smith Co., York, Pa.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26 Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, HYDRANT
Edson Corp., 49 D St., South Boston, Mass.

PUMPS, JETTING
Northrop & Co., Inc., 50 Church St., New York City.

PUMPS, PORTABLE
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Economy Pumps, Inc., 1024 Weller Ave., Hamilton, Ohio.
Fairbanks, Morse & Co., 600 So Michigan Ave., Chicago, Ill.
Homelite Corp., Port Chester, N. Y.
Morris Machine Works, Baldwinsville, N. Y.
Northrop & Co., Inc., 50 Church St., New York City.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26 Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, ROTARY
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S Michigan Ave., Chicago, Ill.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26 Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, SELF PRIMING
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Place New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Homelite Corp., Port Chester, N. Y.
Northrop & Co., 50 Church St., New York City.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Roots-Connersville Blower Corp., Connersville, Ind.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS SEWAGE
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Dorr Co., 570 Lexington Ave., New York City.
Economy Pumps, Inc., Hamilton, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26 Los Angeles, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, SLUDGE
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Dorr Co., 570 Lexington Ave., New York City.
Fairbanks, Morse & Co., 600 S Michigan Ave., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, SUCTION AND FORCE
Ralph B. Carter Co., 53 Park Place, New York City.
The Deming Co., Salem, Ohio.
Edson Corp., 49 D St., South Boston, Mass.
Morris Machine Works, Baldwinsville, N. Y.
Northrop & Co., 50 Church St., New York City.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, SUMP
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Economy Pumps Inc., Hamilton, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, TURBINE
The American Well Works, Aurora, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26 Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, VACUUM
Allen-Billmyre Corp., 449 Fayette Ave., Mamaroneck, N. Y.
Barrett, Haentjens & Co., Hazleton, Pa.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumps Inc., Hamilton, O.
Gardner-Denver Co., Quincy, Ill.
Roots-Connersville Blower Corp., Connersville, Ind.
Vogt Brothers Mfg. Co., Louisville, Ky.
Worthington Pump & Mach. Corp., Harrison, N. J.

RAIN GAGES
M. C. Stewart, Ashburnham, Mass.

RATE OF FLOW CONTROLLERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

RATE OF FLOW RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Neptune Meter Co., 50 W. 50th St New York City.
Northrop & Co., 50 Church St., New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

REAMERS
Mueller Co., Decatur, Ill.

RECARBONATORS
The American Well Works, Aurora, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

RECORDING INSTRUMENTS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

RECUPERATOR
Carborundum Co., Perth Amboy, N. J.

REFRACTORIES
Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.

REGULATORS, SEWAGE
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

REGULATORS (Pressure), WATER AND GAS
American Radiator Co., Bessemer Bldg., Pittsburgh, Pa.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Connelly Iron Sponge and Governor Co., 3154 S. California Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Mueller Co., Decatur, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

RESERVOIRS
(See Standpipes and Tanks)

ROBOT FILTER AND SOFTENER OPERATORS
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

RUST PREVENTION
(Tanks, Pipe Lines, Submerged Metal)
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio. (Cathodic Protection)
Philadelphia Quartz Co., 124 S. Third St., Philadelphia, Pa.
Rusta Restor Corp., 1480 W. State St., Fremont, Ohio. (Cathodic Protection.)

SADDLES, PIPE
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.

SAMPLERS AND SAMPLING TABLES
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

SAND EXPANSION INDICATORS
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Stuart Brumley Corp., Baltimore, Md.

SCALE PREVENTION CHEMICALS
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.

Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Permutit Co., 330 W. 42nd St., New York City.

SCREENS, INTAKE
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Rodney Hunt Machine Co., Orange, Mass.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SCREENS, SAND, GRAVEL AND STONE
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SCREENS, SEWAGE
The American Well Works, Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Rodney Hunt Machine Co., Orange, Mass.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

SCREENS, WATER WELL
Layne & Bowler, Inc., Memphis, Tenn.

SERVICE BOXES
Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 So. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
United Concrete Form Products Co., 5243 W. 25th Pl., Chicago, Ill.

SEWAGE EJECTORS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumps, Inc., 1024 Weller Ave., Hamilton, Ohio.

SEWAGE SAMPLERS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Proudman & Goossen, New Canaan, Conn.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

SEWAGE SCREENING GRINDERS
The American Well Works, Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Royer Foundry & Mach. Co., Kingston, Pa.

SEWAGE SLUDGE INCINERATOR
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Morse Boulger Destructor Co., 216 East 45th St., New York City.
Nichols Engineering & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Underpinning & Foundation Co., 155 E. 44th St., New York City.

SEWER CLEANERS
Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
W. H. Stewart, P. O. Box 767, Syracuse, N Y.

SEWER PIPE
(See Pipe, Sewer)

SEWER PIPE JOINTS
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
L. A. Weston, Adams, Mass.

SEWER PIPE LOCATORS
Frank N. Blake, North Adams, Mass.

SEWER RODS
Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
W. H. Stewart, P. O. Box 767, Syracuse, N Y.

SHEETING
American Rolling Mill Co., Middletown, Ohio.
Armco Drainage Products Assn., Middletown, Ohio.

SIGHT FEEDERS (For Chemical Pumps)
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

SIPHONS (Sewage)
The American Well Works, Aurora, Ill.
Armco Drainage Products, Assn., Middletown, Ohio.
Ralph B. Carter Co., 53 Park Place, New York City. (Alternating.)
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

SLEEVES, PIPE REPAIR
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

SLEEVES, TAPPING (Valve)
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville Ky.

SLUDGE COLLECTORS
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pemutit Co., 330 W. 42nd St., New York City.

SLUDGE DISINTEGRATORS
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Royer Foundry & Mach. Co., 158 Pringle St., Kingston, Pa.

SLUDGE PUMPS
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Dorr Co., 570 Lexington Ave., New York City.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

SODA ASH
Diamond Alkali Co., Pittsburgh, Pa
Hood Chemical Co., 450 W. 31st St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Works, 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
Solvay Sales Corp., 40 Rector St., New York City.

SODIUM ALUMINATE
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

SODIUM PHOSPHATES (Glassy)
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.

SODIUM SILICATE
Diamond Alkali Co., Pittsburgh, Pa
General Chemical Co., 40 Rector St., New York City.
Philadelphia Quartz Co., 124 S. Third St., Philadelphia, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Standard Silicate Division, Diamond Alkali Co., Pittsburgh, Pa.

SOFTENERS AND PURIFIERS
The American Well Works, Aurora, Ill.
Calgon, Inc., Hagan Bldg., Pittsburgh,, Pa.
Dorr Co., Inc., 570 Lexington Ave., New York City.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.

SPEED REDUCERS, TRANSMISSION
De Laval Steam Turbine Co., Trenton, N. J.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.

SPRINKLING FILTERS (Sewage)
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

STACKS
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

STACKS, FUME
Johns-Manville, 22 E. 40th St., New York City.

STANDPIPE AND TANKS
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

STANDPIPE AND TANK PRESERVATION
(See Cathodic Protection Process.)

STIRRERS (Laboratory)
Dorr Co., 570 Lexington Ave., New York City.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Phipps & Bird, Inc., Sixth & Byrd Sts., Richmond, Va.
Stuart Brumley Corp., Baltimore, Md.

STOKERS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Link-Belt Co., 2410 W. 18th St., Chicago, Ill.

STORAGE TANKS
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
National Fireproofing Corp., 202 E. Ohio St., N.S., Pittsburgh, Pa.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

STRAINERS, SUCTION
Barrett, Haentjens & Co., Hazleton, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Edson Corp., 49 D St., South Boston, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.

SULPHATE OF ALUMINA
Activated Alum Corp., Curtis Bay, Baltimore, Md.
General Chemical Co., 40 Rector St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Stuart Brumley Corp., Baltimore, Md.

SULPHUR DIOXIDE (Liquid)
Dow Chemical Co., Great Western Div., 310 Sansome St., San Francisco, Calif.
Virginia Smelting Co., West Norfolk, Va.

SUPER-CHLORINATION UNITS (See Chlorinators)

SWIMMING POOL EQUIPMENT
Ralph B. Carter Co., 53 Park Place, New York City.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

SWIMMING POOL TESTING OUTFITS (pH and Chlorine)
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.

Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

SWITCHBOARDS
Climax Engineering Co., Clinton, Iowa.

SWITCHES, FLOAT, TRANSFER AND REMOTE CONTROL
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

TANKS, ELEVATED STEEL
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

TANK PRESERVATION
(See Cathodic Protection Process.)

TANKS, RUBBER LINED
Atlas Mineral Products Co., Mertztown, Pa.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

TANKS, STEEL
(See Tanks, Elevated Steel)

TAPPING MACHINES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

TASTE & ODOR CONTROL GRAPHS
Darco Corp., 60 E. 42nd St., New York City.

TASTE & ODOR REMOVAL CHEMICALS
Activated Alum Corp., Curtis Bay, Baltimore, Md.
American Norit Co., Jacksonville Fla.
Darco Corp., 60 E. 42nd St., New York City.
Graver Tank & Mfg. Co., East Chicago, Ill.
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., Inc., 230 Park Ave., New York City.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Stuart Brumley Corp., Baltimore, Md.
Virginia Smelting Co., West Norfolk, Va.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

TESTERS (Water Meter)
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
National Meter Division of Pittsburgh Equitable Meter Co., 4221 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Worthington-Gamon Meter Co., Newark, N. J.

THICKENERS
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
The Elmco Corp., P. O. Box 300, Salt Lake City, Utah.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

TOOLS, PNEUMATIC
Schramm, Inc., Westchester, Pa.
Sullivan Machinery Co., Michigan City, Ind.

TRAPS, DRIP, FLAME, SEDIMENT
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

TRICKLING FILTER UNDERDRAINS
(See Filter Underdrains.)

TRICKLING FILTERS (High Rate, High Capacity)
The American Well Works, Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Co., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

TRITURATORS
(See also Grinders)
Chain Belt Co., Milwaukee, Wis.

TUNNEL LINER PLATES
American Rolling Mill Co., Middletown, Ohio.
Armco Drainage Prod. Assn., Middletown, Ohio.

TUNNEL MACHINERY, BORING & LINING
Jeffrey Mfg. Co., Columbus, Ohio.

TURBINES, HYDRAULIC
De Laval Steam Turbine Co., Trenton, N. J.
Morris Machine Works, Baldwinsville, N. Y.
S. Morgan Smith Co., York, Pa.

TURBINES, STEAM
De Laval Steam Turbine Co., Trenton, N. J.
Morris Machine Works, Baldwinsville, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

VALVE BOXES
Central Foundry Co., 386 Fourth Ave, New York City.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVE BOX LOCATORS
Northrop & Co., Inc., 50 Church St., New York City.

VALVES
American Rolling Mill Co., Middletown, Ohio.
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Armco Drainage Products Assn., Middletown, Ohio.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hays Mfg. Co., Erie, Pa.
Rodney Hunt Machine Co., Orange, Mass.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
S. Morgan Smith Co., York, Pa.
Vogt Bros. Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVES, AIR RELEASE
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave. Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, AIR & VACUUM
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.
Roots-Connersville Blower Corp., Connersville, Ind.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. D. Wood Co., 400 Chestnut St., Chicago, Ill.

VALVES, ALTITUDE
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 So. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Northrop & Co., Inc., 50 Church St., New York City.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.

VALVES, CHECK
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Barrett, Haentjens & Co., Hazleton, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Connelly Iron Sponge and Governor Co., 3154 So. California Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hays Mfg. Co., Erie, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
S. Morgan Smith Co., York, Pa.
The Smolensky Valve Co., Inc., Cleveland, Ohio.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
R. D. Wood Co., Philadelphia, Pa.

VALVES, CHLORINE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

VALVES, CONE
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, EMERGENCY TRIP
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Ross Valve Mfg. Co., Troy, N. Y.

VALVES, FLAP
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Connelly Iron Sponge and Governor Co., 3154 So. California Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, FLOAT
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co. 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
Northrop & Co., Inc., 50 Church St., New York City.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

VALVES, FOOT
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Edson Corp., 49 D St., South Boston, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
The Smolensky Valve Co., Inc., Cleveland, Ohio.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, FOUR WAY
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Roberts Filter Mfg. Co., Darby, Pa.

VALVES, GATE
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.

Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVES, HYDRAULIC CYLINDER OPERATED

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
S. Morgan Smith Co., York, Pa.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, MOTOR OPERATED

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, MUD AND PLUG

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Brothers Mfg. Co., Louisville, Ky.

VALVES, PRESSURE REDUCING

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Connelly Iron Sponge and Governor Co., 3154 So. California Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith, York, Pa.

VALVES, PUMP

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., N. Y., N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
The Smolensky Valve Co., Inc., Cleveland, Ohio.

VALVES, RELIEF

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hays Mfg. Co., Erie, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Decatur, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

VALVES, RUBBER, GLASS AND LEAD LINED

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.

VALVES, SPECIAL AUTOMATIC

Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Barrett, Haentjens & Co., Hazleton, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Northrop & Co., Inc., 50 Church St., New York City.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, WATER METER SPECIAL

Ford Meter Box Co., Wabash, Ind.

VARIABLE SPEED TRANSMISSIONS

Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Omega Machine Co., 3409 E. 18th, Kansas City, Mo.

VENTURI TUBES

Bailey Meter Co., 1072 Ivanhoe, Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

VIBRATORS, ELECTRO-MAGNETIC

Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

WASTE GAS BURNERS

Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

WATER ANALYSIS EQUIPMENT AND REAGENTS

Chemlab Specialties Co., 52 Alvarado Road, Berkeley, Calif.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
E. Leitz, 730 Fifth Ave., N. Y., N. Y.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., Sixth & Byrd, Richmond, Va.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

WATER HAMMER ARRESTERS

Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
Water Hammer Arrester Corp., 161 W. Wisconsin Ave., Milwaukee, Wis.

WATER LEAK, LOCATING INSTRUMENTS

S. F. Ferguson, Douglas Hotel Bldg., Newark, N. J.
Fisher Research Lab., 1961-63-65 University Ave., Palo Alto, Calif.
Northrop & Co., Inc., 50 Church St., New York City.
Pitometer Co., 50 Church St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

WATER LEVEL RECORDERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

WATER MAIN CLEANING

National Water Main Cleaning Co., 50 Church St., New York City.
Flexible Underground Pipe Cleaning Co., 9059 Venice Blvd., Los Angeles, Calif.
Stuart Brumley Corp., Baltimore, Md.

WATERPROOFING PAINTS, COMPOUNDS AND MATERIALS

General Paint Corp., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.
Modern Waterproofing Paint Co., 1270 Sixth Ave., New York City.
Reilly Tar & Chem. Corp., Merchants Bank Bldg., Indianapolis.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.
Sherwood Waterproofing Corp., 53 Park Pl., New York City.
Standard Dry Wall Products, Inc., New Eagle, Pa.
Stuart Brumley Corp., Baltimore, Md.
Sika, Inc., Passaic, N. J.
Wailes Dove-Hermiston Corp., Westfield, N. J.

WATER SOFTENING CHEMICALS AND COMPOUNDS

Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Mathieson Alkali Works, 60 East 42nd St., New York City.
National Lime Assn., 927 Fifteenth St. N. W. Washington, D. C.
Permutit Co., 330 W. 42nd St. New York City.
Pittsburgh Plate Glass Co. Columbia Chemical Div. 30, Rockefeller Plaza, New York City.
Stuart Brumley Corp., Baltimore, Md.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.
Zeolite Chemical Co., 140 Cedar St., New York City.

WATER SOFTENING EQUIPMENT

The American Well Works, Aurora, Ill.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Chain Belt Co., 1000 W. Bruce St., Milwaukee, Wis.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dorr Co., Inc., 570 Lexington Ave., New York City.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 221 W. Adams St., Chicago, Ill.
Link Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 3409 E. 18th, Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Stuart Brumley Corp., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Zeolite Chemical Co., 140 Cedar St., New York City.

WATER STABILIZATION

The American Well Works, Aurora, Ill.
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

WATER SUPPLY CONTRACTORS

Ranney Water Collector Corp. of New York, 1510 Heyburn Bldg., Louisville, Ky.
Fritz Ziebarth, 820 W. Esther St., Long Beach, Calif.

WATER TREATMENT FOR SCALE AND CORROSION

Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
The Permutit Co., 330 West 42nd St., New York City.
Stuart Brumley Corp., Baltimore, Md.

WATER WASTE SURVEYS

Aqua Survey & Instrument Co., 140 Marlowe Ave., Cincinnati, Ohio.
S. F. Ferguson, Douglas Hotel Bldg., Newark, N. J.
Pitometer Co., 50 Church St., New York City.
Simplex Valve & Meter Co. 68th & Upland Sts., Philadelphia, Pa.

WEATHERPROOF PAINTS, ROOF COATINGS

American Colloid Co., 363 W. Superior, Chicago, Ill.
General Paint Corp., 3001 Mayfield Road, Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis.

WRAPPING, PIPE
(See Pipe, Wrapping)

WRENCHES, REVERSIBLE RATCHET

Dresser Mfg. Co., Bradford, Pa.

ZEOLITE AND ZEOLITE SOFTENERS

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 221 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.
Zeolite Chemical Co., 140 Cedar St., New York City.

INFORMATION ON WATER AND SEWAGE WORKS PROBLEMS

(WHERE TO FIND IT)

By LINN H. ENSLOW

Editor, "Water Works and Sewerage"

IT goes without saying that information required by water works men and sewage works operators is not concentrated in two or three books. The nearest approach to concentrated information for water works men is found in the manuals published by the American Water Works Association—"Water Works Practice," the "Purification Manual and the "Accounting Manual."

Text books, manuals, hand-books, journals, and catalogs are named in the attached list of recommended reference works for water and sewage works men.

The list represents the majority opinions of operating men, managers, engineers and chemists called on to offer suggestions in making up a set of reference works. It is an attempt to recommend those books of greatest usefulness.

LIST NO. 1 —FOR WATER WORKS MANAGERS AND OPERATORS

[For Small and Moderate Size Systems.]

Books	*Publishers*	*Authors*
Manual of Water Works Accounting	Am. Water Works Assn., New York City	Various
Manual of Water Quality and Treatment	Am. Water Works Assn., New York City	Various
The Operation of Water Filtration Plants (F)	N. C. State Dept. Health, Raleigh, N. C	
Water Supply Control (nominal charge)	N. Y. State Dept. Health, Albany, N. Y	
Water Works Handbook ($7.00)	McGraw-Hill Co., New York City	Flynn, Weston & Bogert
Water Purification Control, 2nd Edition ($1.75)	Williams & Wilkins, Baltimore, Md	Hopkins
Standard Methods of Water Analysis, 8th Ed. ($2.50)	A. P. H. A. and A. W. W. A., New York City	Various
Lab. Manual—Chemical & Bacterial Analysis Water and Sewage, 2nd Edition ($2.50)	McGraw Hill Co., New York City	Theroux, Eldridge, Mallman
Water Purification ($7.00)	McGraw Hill Co., New York City	Ellms
Copper Sulphate in Control of Micro Organisms (F)	Phelps Dodge Refining Corp., New York City	Hale
Pump Data (F)	Economy Pumping Mach. Co., Chicago	
Conversion Factors for Engineers (F)	The Dorr Co., New York City	
Engineering Data in Flow of Fluids in Pipes (F)	Crane Co., Chicago	
Bul. No. 21 (a Handbook on Hydraulics) (F)	National Tube Co., Pittsburgh, Pa	
Handbook of Cast Iron Pipe (F)	Cast Iron Pipe Research Assn., Chicago	
Elements of Water Supply Engineering (2nd Ed.)	John Wiley & Sons, New York City	Waterman
Technical Bulletins on Chlorination (F)	Wallace & Tiernan Co., Newark, N. J	Various
Hydraulic Tables—3rd Ed. ($2.00)	John Wiley & Sons, New York City	Williams & Hazen
Handbook on Fire Protection ($4.50)	D. Van Nostrand Co., New York City	Crosby, Fiske & Forster
Fire Engine Tests and Fire Stream Tables (F)	National Board of Fire Underwriters, N. Y. C	
Plumber's Handbook ($4.00)	McGraw-Hill Co., New York City	Dibble
Examination of Water—6th Ed. ($3.00)	John Wiley & Sons, New York City	Mason & Buswell
Public Water Supplies—4th Ed. ($6.00)	John Wiley & Sons, New York City	Turneaure & Russell
American Civil Engineering Handbook—5th Ed. ($8.00)	John Wiley & Sons, New York City	Merriman & Wiggin
Lefax—Data Sheets for Loose Leaf Note Books	Lefax, Inc., Philadelphia, Pa	Various
Water Supply & Treatment (F)	National Lime Assn., Washington, D. C	Hoover
Treatment of Municipal and Industrial Waters—Tech. Bul. No. 8 (F)	The Solvay Process Co., New York City	
A. B. C. of Hydrogen Ion Control (F)	LaMotte Company, Baltimore, Md	
Modern P. H. Control (F)	W. A. Taylor Co., Baltimore, Md	
Microscopy of Drinking Water (4th Ed. $7.00)	John Wiley & Sons, New York City	Whipple-Fair
Plane Surveying ($3.50)	John Wiley & Sons, New York City	Tracy
Water Purification for Plant Operators ($2.50)	McGraw-Hill Co., New York City	Norcom and Brown
Water Treatment and Purification ($2.50)	McGraw Hill Co., New York City	Ryan
Water Rate Structures in America (F)	Public Service Commission of Wisconsin, Madison, Wis	

(F) Available as Free Publication at this writing.

Journals and Magazines (Applies to Lists 1 and 2)

Journal and Monographs of the American Waterworks Association

Journal of the New England Water Works Association.

Current Water Works Technical Magazines and Trade Papers.

LIST NO. 2—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE WATER WORKS
(In addition to List No. 1)

Books	*Publishers*	*Authors*
Fresh Water Biology ($7.00)	John Wiley & Sons, New York City	Ward & Whipple
Fresh Water Algae ($6.00)	McGraw-Hill Co., New York City	Smith
Ground Water ($6.00)	McGraw-Hill Book Co., New York City	C. F. Tolman
Design of Dams ($5.00)	McGraw-Hill Boook Co., New York City	Hanna and Kennedy
Elements of Water Bacteriology—5th Ed. ($2.50)	John Wiley & Sons, New York City	Prescott & Winslow
"Industrial Water Supplies" (nominal charge)	Ohio Geological Survey, Columbus, Ohio	C. W. Foulk
pH and Its Practical Application ($3.50	Williams & Wilkins Co., Baltimore, Md.	LaMotte, Kenny & Reed
Elimination of Tastes and Odors in Water ($5.00)	McGraw-Hill Co., New York City	Baylis
Boiler Feedwater Purification ($4.00)	McGraw-Hill Co., New York City	Powell
Chemistry of Water and Sewage Treatment****	Chemical Catalog Company, New York City****	Buswell
Water Borne Typhoid Fever Outbreaks (nominal)	Am. Public Health Bureau	Wolman & Gorman
Textbook of Bacteriology ($8.00)	D. Appleton & Co., New York City	Zinser & Jones
Corrosion; Causes and Prevention ($7.00)	McGraw-Hill Co., New York City	Speller
Water Supply Paper No. 658 (Quality of Waters) (nominal)	U. S. Geological Survey, Washington, D. C.	Stabler
Water Supply and Sewerage ($5.00)	McGraw-Hill Co., New York City	Steel
Water Supply Engineering (3rd Ed. $6.00)	McGraw-Hill Co., New York City	Babbitt & Doland
Handbook of Applied Hydraulics	McGrawHill Co., New York City	Various
Hydraulic Measurements	John Wiley & Sons, Inc.	Addison
Handbook of Hydraulics ($4.00)	McGraw-Hill Co., New York City	King
Concrete Engineers' Handbook ($6.00)	McGraw-Hill Co., New York City	Hool & Johnson
Pocket Companion (nominal)	Carnegie Steel Corp., New York City	
Business Law for Engineers ($4.00)	McGraw-Hill Co., New York City	Allen
Mechanical Engineers' Handbook—11th Ed. ($5.00)	John Wiley & Sons, New York City	Kent
Elements of Hydraulics ($1.50)	John Wiley & Sons, New York City	Merriman
The Hardy Cross Method of Distribution System Design.	Univ. of Illinois Engr. Exp. Sta. Bul. No. 286	Hardy Cross
Guiding Principles of Public Service Regulations (3 Vols.)	Public Utilities Reports, Inc., Rochester, N. Y.	Spurr
Theory and Practice of Public Utility Valuation****	McGraw-Hill Co., New York City****	Maltbie
Public Utility Rates****	McGraw-Hill Co., New York City****	Barker
Public Utility Rate Structures ($4.00)	McGraw-Hill Co., New York City	Nash
Business Administration for Engineers ($5.00)	McGraw-Hill Co., New York City	Harding & Canfield
Summary of Census Data on Water Treatment Plants in the United States	Am. Water Works Assn. Reprint	U. S. Pub. Health Service
Index to Jour. of A. W. W. A.—1881-1933 ($2.00)	Am. Water Wks. Assn., New York City	

****Out of print. Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.

For Journals see list No. 1.

LIST NO. 3—FOR OPERATORS AND MANAGERS OF SMALL SEWAGE WORKS**

Books	*Publishers*	*Authors*
Principles of Sewage Treatment (F)	National Lime Assn., Washington, D. C.	W. Rudolfs and Staff
Operation and Control of Sewage Treatment Plants	New York State Dept. Health	N. Y. State Dept. Health
Sewage Treatment ($3.00)	John Wiley & Sons, Inc., New York City	Imhoff and Fair
Sewerage and Sewage Disposal Text Book ($6.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Sewage Treatment Works ($6.00)	McGraw-Hill Book Co., New York City	Keefer
Bulletins Nos. 59, 68, 69, 84 and 86 (F)	Iowa State College, Ames, Iowa	Various
Manual of Sewage Works Operation (nominal)	New Jersey Sewage Expt. Sta., New Brunswick, N. J.	
Reprints of Technical Papers on Chlorine in Sewage Treatment (F)	Wallace & Tiernan Co., Newark, N. J.	Various
Chlorination in Sewage Treatment (F)	Amer. Pub. Health Assn., N. Y. C.	Committee Reports
Chemical Treatment of Sewage (nominal)	Amer. Pub. Health Assn., N. Y. C.	Committee Report
Standard Methods of Water and Sewage Analysis ($2.50)	Amer. Pub. Health Assn., N. Y. C.	A. W. W. A.-A. P. H. A.
Laboratory Manual of Water and Sewage Analysis ($2.50)	McGraw-Hill Co., New York City	Theroux, Eldridge & Mallman
Sewer Rentals ($1.50)	Am. Public Works Assn., Chicago	Various

Journals and Magazines

Sewage Works Journal—(Official publication, Sewage Works Federation)
Current Sewerage Magazines

LIST NO. 4—FOR MANAGER, CHEMISTS AND OPERATORS OF LARGE SEWAGE WORKS**
(In addition to List No. 3)

Books	*Publishers*	*Authors*
American Sewage Practice Vol. 3, Sewage Treatment (1935 Edition) ($7.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Solving Sewage Problems ($6.00)	McGraw-Hill Co., New York City	Fuller & McClintock
Sewerage and Sewage Treatment—4th Ed. ($5.00)	John Wiley & Sons, New York City	Babbitt
The Chemistry of Water and Sewage Treatment****	Chemical Catalog Co., New York****	Buswell
The Hoover Plumbing Code (B. H. 13) (nominal)	U. S. Bureau of Standards	
Sewerage and Sewage Treatment—5th Ed. ($5.00)	Intl. Text Book Co., Scranton, Pa.	Hardenberg
Sewerage, 11th Ed. ($4.50)	John Wiley & Sons, New York City	Folwell
Sewage Disposal****	John Wiley and Sons, New York City****	Kinnicutt, Winslow & Pratt
Modern Sewage Disposal ($3.50)	Federation of Sewage Works Assns., New York City	Various
Sewers (25 shillings)	Chapman & Hall, London	Bevan and Rees
Industrial Waste Treatment Practice ($5.00)	McGraw-Hill Co., New York City	Eldridge

(F) Available as Free Publication at this writing.
****Out of print. Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.

***Note*—Sewerage men should examine Lists 1 and 2—also for several (F) publications of value to all alike—for instance, "Conversion Factors for Engineers" and the hand-books of pipe and pump data.

PROBLEMS IN MUNICIPAL WATERWORKS MANAGEMENT

By L. R. HOWSON
Alvord, Burdick and Howson, Engrs.
Chicago, Illinois

THE term "management" as used in this discussion is much broader than the usual understanding of the process of operating a water works system. As here used, "management" includes a well formulated construction program, a sound financial policy, economical administration of operations, and the equitable allocation of revenues through the medium of fair rates, all coordinated into a unified interrelated whole.

The normal American water works is a growing institution. In predepression times, the average American city added about 3 per cent to its population each year. Inasmuch as the expansion of water facilities in general parallels the growth in population the expenditures for new construction to care for this expansion have averaged about $1.50 per capita per year. It is apparent, therefore, that a substantial part of the total water works revenues have been required for financing new construction either directly from earnings or indirectly through fixed charges on construction cost. This proportion of revenues has varied from 10 per cent to 25 per cent of the total. In recent years the rate of population growth has been relatively slow in most cities, but due to the ever rising standards of water service the investment has continued its growth.

In cities which exceed the general average rate of growth (approximately 35 per cent per decade), the requirements for capital expenditures will necessarily be larger and methods of financing, other than outlined herein, may be necessary. This discussion relates primarily to the average American city.

Every municipal water works should be self-supporting and self-perpetuating. The revenues and the rates on which they are based must be adequate to support the present service and to provide orderly expansion to care for the growth in water requirements. Adequate water rates and sound construction and financial policies go hand in hand.

Financial Policy

It is believed that municipal water plants should develop a sound financial policy which, through rates, will provide sufficient revenue to pay operating expenses, interest and amortization on outstanding debt, if any, an amount sufficient to cover ordinary additions to the water works such as distribution system extensions, meters, etc., and in addition an amount to cover the average annual requirement for major additions.

The obvious result of such a financial policy is to gradually retire all outstanding indebtedness and to build a well distributed construction program from revenues.

It will be noted in the above itemization of funds to be secured from revenues, nothing is said about depreciation. It is the writer's belief that if the present generation of consumers pays interest on the outstanding debt (if any) and provides for its amortization requirements, and in addition pays for new construction out of earnings, it is certainly the responsibility of succeeding generations of consumers to provide for replacements of property from their current revenues. To charge present consumers for both amortization of debt and depreciation reserve, for replacement of previously amortized property, is an unwarranted duplication of charges.

Considered over a long term, the cost of financing from current revenues is only about 60 per cent as costly to the consumer as financing by bond issues. Costs are amortized as incurred without interest charges. Financing from current revenues has several other very definite advantages, including the following:

1. Through being able to provide new construction when needed without resort to bond issues, the facilities are available when needed and a high standard of service is uniformly maintained.
2. Delays incident to the failure to vote bond issues and the political exigencies surrounding their passage are obviated.
3. When coordinated with a properly developed, comprehensive construction program, the bulges in fixed charges incident to bond issues are avoided, and most important.
4. The attention of the consumers is focused upon service rather than cost as is the case when financing is done by bond issues. By financing new construction from revenues the Water Department, rather than the politicians, has control of its ability to finance and furnish adequate service.

Construction Program

It is desirable that there be as few changes in the rate structure as practicable. If new construction is financed from current revenues, it is therefore important that construction expenditures be well distributed. The prime essential to the distribution of construction expenditures is the formulation of a carefully studied, comprehensive program covering the requirements for expansion to serve both the near and distant future. Such a program should currently be made and kept 20 to 30 years ahead of the present time. It should be reviewed at periodic intervals not exceeding 10 years.

The formulation of such a program necessarily starts with a forecast of population, industrial growth and water requirements. Each part of the present system is investigated with respect to its ability to meet these requirements, its present and probable future deficiencies and the time when it will become deficient ascertained, and the various practicable means of correcting deficiencies outlined, estimated as to cost and evaluated.

With such a well formulated construction program it will usually be possible to so forecast requirements with reasonable accuracy and to so provide construction essential to meet them, that the flow of capital into construction can be kept at a relatively uniform rate.

Where such a construction program has been formulated and adopted, the following results have usually been accomplished:

1. Funds are provided for construction when needed and not before, thus on the one hand saving the fixed charges on expenditures which otherwise might be made before necessary, and on the other hand obviating the inadequacies in service resulting from delays in building large expansion programs.
2. It affects the most practicable uniformity of construction requirements and expenditures. Construction expenditures follow a smooth line rather than a saw tooth course. Smaller expenditures for construction are made each year which is preferable to accumulated deficiencies corrected at infrequent intervals.
3. By such a comprehensive program of development, each year's construction is designed to serve not only the immediate needs but to fit in best with the ultimate requirements, thus minimizing future obsolescence.

Economical Operations

It should, of course, be the aim of all management to operate as economically as possible consistent with furnishing excellent water service. Sometimes, but not as frequently as ordinarily thought, there is political interference in municipal plant operations which adversely affects economy. Economy in operations does not just happen; it is created. Among the factors contributing to it are:

1. Good bookkeeping and accounting practice.
2. Concise yet comprehensive daily, weekly, and monthly comparative operating reports.
3. An annual report, properly arranged for comparative use.
4. Comparison of operating statistics of the particular plant with others of its type and class.

Good bookkeeping is essential to economical administration. The introduction of standard methods of accounting for water utilities by state utility commissions has been of great advantage. Unfortunately in most states the adoption of this system is mandatory only for private utilities. It is believed that every municipal water works should adopt standard accounting practice *without being compelled to do so.* The use of standard accounting methods has been of great advantage to the private utilities; it will be of even greater advantage to municipal plants whose accounting practices are frequently more lax.

There should be a system of daily, weekly, and monthly reports from department heads to the manager. These should be informatory rather than routine, brief, yet sufficiently explicit to enable the manager to promptly detect and correct variations from normal.

Municipal water works should prepare their annual reports along standard lines. Some years ago a joint committee of the N.E.W.W. Association and the American W.W. Association prepared a form titled "Essential Statistics for Annual Reports

of Water Works." Mr. Metcalf and Mr. Rogers represented this Association. If all municipal plants would use this form (see Water Works Manual of the A.W.W.A.) the comparison of the individual plant's operating with others would be much facilitated and much more accurate.

There are two primary reasons for an annual report:

1. The Beneficial Effect on the Management Itself

Just as the author of a paper usually derives more benefit from its preparation than those who read it, so the greatest benefit from a good annual water works report falls upon the management. The preparation and analysis of the statistical data is essential to the best understanding of one's particular property. The preparation of the annual report should not be a routine matter consisting of tabulations by accountants compiled once a year. Its data should be constantly before the manager or superintendent, month by month, in form to disclose any variations from previous months or years.

2. Its Value in Indicating Possibility of Improvement

Sometimes we learn much by a comparison with others in the same line of endeavor. If the annual report data is in standard form, comparison is facilitated and greater accuracy assured. By comparison items are easily selected for more detailed analysis. For illustration, in a recent water rate investigation, where it was first of all necessary to determine the reasonable operating expenses of the future, it was found that the unit costs of meter reading and collection were approximately double the average in other cities of similar size. An investigation disclosed that there were currently approximately 30 per cent of the consumers delinquent and the total delinquencies amounted to one-third of one year's revenue. All current bookkeeping was done by machine but delinquencies were transcribed to the bills by hand. This handling of about 30 per cent of the accounts more than doubled the normal cost of collection and bookkeeping in that particular city. It was accordingly recommended that every effort be made to reduce the present delinquencies, that a firm shut-off policy be adopted and followed without political interference, and that in cases where it was claimed that absolute poverty prevented payment of the bill, the "trickle treatment" be administered. [This consists in placing a perforated disc in the consumer's connection with an opening so small that the flow is restricted to an amount which will furnish water for the absolute necessities of sanitation, but which requires so long to fill a bucket or tea kettle as to provide every incentive of paying the bill as soon as possible. This "treatment" has been quite successful in reducing delinquencies.]

By analysis and comparison with other cities of comparable size it was found that in a particular city, while all other departments were relatively efficient, the commercial department was inefficient throughout. The average number of meters read per employe per day was approximately 30, and the number of bills gotten out per clerk per day was less than 20. The annual commercial expense of meter reading, collecting, billing, and accounting averaged approximately $3.00 per meter as compared to a general average of $1.50 or less. The number of consumer accounts handled per employe was only approximately 600 per year, as compared to a general average of 1,200 and an outstanding performance, such as Cincinnati, or nearly 1,800.

In another city it was found that the automobile expense was excessive by comparison with 14 other cities in the same general population classification. It was found that the number of cars per 100,000 population was 22 as compared to the average of 12½ in the other cities, and the number of cars per 100 miles of mains was 10 as compared to the general average of 5.5. Investigation disclosed that these cars were individually assigned, unmarked except by a special license plate, that the average mileage per car per mile of main in the system was approximately 2½ times that of the average in other cities, that the average annual cost expressed in terms of dollars per mile of main or per capita served was about three times that of the average city. By a pooling of cars and the providing of a central garage, a saving of approximately $40,000 per year was practicable.

These figures are cited simply as illustrative of the benefits that can be derived from keeping records and cost accounting in cities on a standardized basis. The management in any particular city should check his operations with those of similar cities and plants and if the figures are accounted for on the same general basis, they will furnish a helpful guide in locating weak spots in his own organization. Every large organization has some department head with bureaucratic tendencies, sometimes so gradual in their expansion as to escape detection unless checked comparatively with the experience of others. Good reports help to "know thyself" and to do as well as, or better than, others.

Factors Affecting Water Rates

It is the function of the rate schedule to equitably allocate to the various classes of consumers their proper proportions of the total revenue requirements. One of the principal factors in determining fair rates is the proportion of total pumpage which is revenue producing. Obviously the lower the percentage of revenue water the higher the average rate per 1,000 gallons must be. This percentage is affected by such policies as ownership of meters, free water, use of hydrants, etc.

Ownership of Meters

In a considerable number of municipalities the meters are owned by the consumer. Usually when repairs to the meters are made, the consumer pays the expense. A survey of over 80 completely metered water works, classified only with respect to ownership of meters, disclosed the fact that the meters were registering about 6 per cent less of the pumpage in cities where the consumers owned the meters than where they were owned by the utilities. The reason is obvious. The consumer is not interested in accurate registration. The more inaccurate, the better for him as a water meter ordinarily cannot overregister. With increased wear the underregistration increases. Meter repair is an annoyance and expense to the private owner but a means of increasing sales and revenues to the city.

A further disadvantage in consumer ownership arises from the fact that during the period while the meter is removed from his service for inspection or testing, the water is usually furnished to him unmetered through a "jumper" connection. Investigation of consumer ownership practice has disclosed that frequently a "jumper" connection is in position for two months or more. Had the meter been owned by the city, it would have been immediately replaced by another meter. There would be no reason to return the identical meter removed.

The meters are the "cash registers" of a water works. As such they should be owned by the utility, not the consumer. Ownership by the utility, with the accompanying obligation of bearing the cost of repairs and renewals, will ultimately return several times the added expense through increased registration from the reduction in "unaccounted for" water.

Size of Meters

The utility rather than the consumer should make the decision as to the size of meter to install on a service. Analysis of the "unaccounted for" water in a number of plants indicates this decision is worth approximately 5 per cent in the water measured by the meters and sold. One of the most effective means of regulating the demand by consumers for oversize meters is by the inclusion in the rate schedule of a graduated service charge or graduated minimum charge. Theoretically this charge should vary approximately as the ability to use water, that is, as the area of the pipe opening. However, in actual practice it was shown in a recent paper by E. W. Moke (Journal A.W.W.A., June, 1940) that the increase is much less. Taking a ⅝ inch meter as unity, in average practice, the service charge for a 1 inch meter is approximately 60 per cent, a 2 inch meter 30 per cent and a 4 inch meter but 17 per cent of the theoretical.

In the average city over 95 per cent of all meters are ⅝ inch and over 99 per cent are 1 inch and less.

It is, of course, obvious that there is no such thing as "free water." It is just a question as to who pays for it. In equity all water should be sold at schedule rates regardless of the purchaser. If those responsible for municipal policies decide to give "free water," it should be metered in any event and the amount allowed free should be limited with a charge for all excess. Better yet, all such water should pay at some rate even though materially lower than the schedules rates. Public uses or "free water" usually take from 6 to 8 gallons per day per capita.

Consumer Complaints

All complaints should be recorded as to time, cause, locality, and corrective measures taken. Frequent review grouped by causes and localities has helped to avert major dissatisfaction.

Conclusion

In conclusion good management begins with good planning, requires a sound financial policy, alert, analytical administration of its own affairs and a knowledge of others, and the equitable allocation of the revenue requirements among the various classes of consumers.

LEGAL RESPONSIBILITIES OF WATER OPERATORS

By JOHN H. MURDOCH, Jr., Attorney
American Water Works and Electric Co., New York, N. Y.

A WATER works operator has the legal responsibility to install, maintain and operate reasonably adequate and safe facilities and to render reasonably adequate service and to deliver to the public reasonably pure water.

That statement may cover the situation but probably a little more detail would be helpful.

A water works operator has the legal responsibility to obey specific mandatory laws and the lawful orders of the constituted health authorities. It is assumed that you know the laws applicable to your work and that as law abiding citizens you obey laws and lawful orders. A fuller statement of your legal responsibilities is needed.

While such a fuller statement is needed, some limits as to subject matter must be placed.

There have been deliberately eliminated from this paper any matters as to which the legal responsibilities assumed by a water works operator differ because the water plant is owned by a municipality, an authority or a private company. In the matters to be covered here the same principles are applicable *no matter what the type of ownership.* For that reason the phrase "water utility" is used to designate the owner of the plant whether that owner be a municipality, an authority or a private company.

A water utility acts through its individual operators, and when those operators fail in the performance of a duty or responsibility to others, then the water utility has failed. And if damage is caused, then the water utility is liable for money damages. Some types of such failures to perform legal responsibilities are to be considered.

Definitions of Some Terms

To avoid the necessity of long repetitions in this discussion, some definitions are needed. These definitions and the discussion which follow them are not intended to be legally accurate, complete and exhaustive. To make them such would be exhausting and, practical-wise, unnecessary. Besides, this is not a legal treatise on Torts but a short talk among friends. Now for some definitions.

Negligence: "The failure to observe, for the protection of the interests of another person, that degree of care, precaution, and vigilance which the circumstances justly demand, whereby such other person suffers injury." (Cooley on Torts.) Negligence is also defined as "Any conduct which falls below the standard established by law for the protection of others against unreasonable risk of harm."

Standard of Conduct Established by Law: The standard of conduct to which one must conform to avoid being negligent is that of a reasonable man under like circumstances.

Reasonable Man: Reasonable man is a person exercising those qualities of attention, knowledge, intelligence, and judgment which society requires of its members for the protection of their own interests and the interests of others.

Unreasonable Risk: A risk which outweighs the value attached to the conduct which involves it. Illustration: A high pressure pipe line in a busy street may burst and cause damage. To operate such a pipe line, therefore, involves a risk. Its social value outweighs this risk and the placing of it is not conduct involving an *unreasonable risk.* On the other hand, allowing unchlorinated water to be distributed while repairing a chlorinator or because of a depleted supply of chlorine would be conduct involving unreasonable risk.

Negligent Conduct: May be either

(a) An act which the actor as a reasonable man should realize involves an unreasonable risk of causing an invasion of an interest of another, or

(b) A failure to do an act which is necessary for the protection or assistance of another and which the actor is under a duty to do.

Having gone a long way around the hill, let us look for a short cut. When, on principle, is a water works operator negligent? From the defintions this conclusion can be stated: A water works operator is negligent when his conduct brings an unreasonable risk of harm to his consumers or to persons or to property of others; and, when his conduct is not up to that standard of conduct, recognized by water works operators generally as required under like circumstances, to protect from unreasonable risk others to whom a duty is owed. Each operator is judged by a standard established by good practice. And standards of good practice are established by the consensus of opinion of such groups as this Association and others with similar objectives.

Some Legal Principles

Before there is a legal liability for damages in negligence cases certain elements must be present. A statement of these elements is needed.

First: Damages must have been suffered by some person.

Second: This other person must be one to whom the actor owes a duty of protection or assistance.

Third: The actor must have done or failed to do some act.

Fourth: This action or failure to act must have caused the damage.

Fifth: The action or failure to act must have involved an *unreasonable* risk to others.

Sixth: The action or failure to act must not have measured up to the standard of good practice under the circumstances.

Seventh: The failure to act must have been a failure to act in a way in which the actor was under a duty to do.

In short, before there is a legal liability for damages for negligence there must be negligent conduct resulting in damage to a third person to whom a duty is owed.

Examples of Application of Legal Principles

With this background of definitions and legal principles, consideration will be given to three classes of cases in water works operation in which the principles are applied.

Damage Caused by Water Escaping from Mains

One of the frequent, but usually informal complaints against a water utility is that a leaking or broken main floods and damages property. Claims based on such occurrences are not usually covered by public liability insurance, and if the utility is liable the damages collected are often considerable. For these reasons this class of damage will be touched upon briefly.

As was pointed out above, the maintenance and operation of a high pressure water main in a busy public street does involve the risk that water may leak from such main and cause damage to the property, or the persons of innocent people. However, since no other way has yet been found to get water to the places where it is needed in our cities, and since the water is needed at those places for the uses of industry, commerce, domestic life, and fire service, the social value of the service far outweighs the risk involved and the risk is therefore reasonable. That being true, the mere placing and operation of the main is not negligence. The water utility is not an insurer that its mains will not break or leak. *It is not liable for damages merely because water has escaped and caused the damage.* Negligence must be proved.

There have been cases, however, when liability has been imposed and damages paid. One important city paid a large claim when these facts were proved: The main was laid in a ditch below which there was a large sewer; the main was partly supported by timbers which were old and weakened when first installed under the main; known to the water works operators, many subcellars were below the level of the main and sewer; the ditch was opened several times to repair leaks caused by the sinking of the timbers and main; a large section finally broke; and water flooded adjacent cellars. Here we have a perfect example of negligence.

There was damage; the utility owed the duty to the person damaged of so installing and operating its main that no more than a reasonable risk would be involved; the operators of the water utility did not support their main; this failure of support caused the damage; the failure to properly support the main was failure to do what a reasonable man would have done under the circum-

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stances. The conduct of the water works operator did not measure up to the standard of good conduct recognized by water works operators generally.

In another city a change in operating conditions as to pressure brought about a pipe line failure and a flooding of property. The line was designed for fifty pounds pressure and light class pipe had been installed. Many years later the system was rearranged and a pressure of one hundred and fifty pounds was put on the line. The line burst and damage was caused. There was negligence here because the act of placing that added pressure on a pipe line not designed to carry it was an act not up to the standard recognized by water works operators generally.

In another case a new line was laid. The street paving above the line kept sinking and at a lower level a "spring" developed. This condition continued for two years without an inspection of its main by the water utility. A major leak eventually developed and resulted in a flooding of cellars. The failure to inspect after the suspicious conditions developed was held to be negligent, as not being up to standard practice under the circumstances. Water works operators have long known the significance of "springs," which suddenly develop along a pipe line, as a suspicious condition which should not be neglected. It pays to locate and stop leaks.

Again, a known and serious leak was left unchecked for a period of twelve hours, during which no attempt was made to check it by closing valves or otherwise, and the flow of water increased due to the worsening of the blow out. The neglect in failing to attempt to stop the flow for a period of twelve hours, after discovery by the water utility, was deemed to be negligence.

It seems, therefore, that the mere fact of water damage from a leaking main is not enough to impose liability but that such liability is imposed when the water works operator has failed in the legal obligation to use the care and skill recognized as standard among operators generally, and when that failure caused injury and damage.

Water-Borne Disease

Ever since it became known that clear, cool, sparkling water, free of objectionable tastes and odors might yet be deadly as a carrier of typhoid and other water borne diseases, every water works operator has had the dread that some day, somehow, an epidemic would strike in his community for which his water utility would be found responsible. It may seem a contradiction in terms, but this very constant dread has been health-giving to ourselves and to our consumers. The dread has brought with it realization of great responsibility and a determination not to be found wanting. Our operators, our chemists, our bacteriologists, our engineers and our utility officers have all devoted their talents to the guarding of our public water supplies against disease. The State and Federal Health Departments have been efficient, resourceful, firm and untiring in the work. Its district engineers have been preaching the gospel of cleanliness, efficiency and constant care in every city and cross roads of our state. To all must go credit for the splendid progress that has been made in the last forty years. The battle has been won but the advanced position must be held by constant attention to duty. We have a call to continued service.

A water works operator has the legal obligation to so operate his facilities that neither through his act nor through his neglect of a duty, lawfully imposed, will water borne disease bacteria reach his consumers. That is *his* obligation.

The water utility is not a guarantor of the quality of the water furnished and by selling it or by rendering water service it does not give an implied warranty that the water is free of harmful bacteria. The reason for this rule seems to be that the volume handled, its sources, the possibilities of contamination by persons or agencies over which the water utility has no control, all combine to make it unwise and unjust to require the utility to guarantee the water. The rendering of water service in great quantities does involve some risk but the risk is reasonable when weighed against the large social advantage of having water delivered by an organization which assumes the obligation of seeing to it that its operators measure up to the standards of such groups as this Association.

However, the water utility is liable for damages caused by negligence of its operators, and such liability has been imposed. Consider some instances.

Occasionally an ill advised operator thinks a little bad water will do no harm and be unnoticed when, due to a break down, no other water is available. The sequel is usually a very sad story.

For twelve hours water was taken through an emergency intake from a highly polluted river. The normal source could not be used because of a break in a line. Deaths followed which were proved to have been caused by drinking water brought into the system from the river. Here was action below the standard and, therefore, negligent.

A chlorine machine broke down and water from a polluted source but clear, cool and sparkling, was, with the full knowledge of the water works operator, fed into the system. Deaths followed, and those deaths were caused by negligence. An operator failed to meet his legal obligations.

In other cases the water works operator used facilities in normal operation which were known to be faulty and in condition to permit pollution of otherwise good water.

In one city a splendid filtration and chlorination plant was in operation. Water from it was taken under very low head some distance through a buried conduit. The conduit was in ground subject to flooding by contaminated water and the conduit was known by the water works operators to have holes through its walls. By the standard of reasonable men in water works operation the conduct of these operators was below par. Negligence resulted in epidemic.

In another case the water works operators of a utility knew that the casing of a water well was bad and that impurities might reach the water through such defective casing. They continued the well in use and were negligent.

Water Safe at Source, Contaminated in Distribution System

The cases which have been brought forward up to this point were cases in which the water works operator failed to live up to his legal obligations in using reasonable care in putting water into the distribution system of the water utility. Under such conditions, the other essentials being proved, the utility would be liable for damages. There are a number of old cases and some new ones where the contamination came into the distribution system after the water left the source. There are some interesting variations of principle in these cases, and further possible variations which deserve thought. The illustrations which follow are in part imaginary but could happen.

A city has two systems for water service. One is high pressure, non-potable, for fire service. The other is high quality potable water. To operate drawbridges in the city and to guard against delays due to possible failure of one system both systems are connected to water driven pistons operating the drawbridges. A valve at each piston was supposed to keep the fire service water out of the lower pressure potable system. Some water works operator forgot to install one of these valves. Many complaints of bad water came from the district near the bridge where the valve was missing. These complaints were heard but unheeded for months until an epidemic developed and pollution of the supply was proved. Here there was negligence on the part of the operator who failed to install the valve; negligence on the part of the operator who conceived of the idea in the first place; and gross negligence on the part of the water works operators who failed to make any investigation as to the cause of the bad water in the neighborhood. None of them lived up to the standard.

Again a case of two systems, one potable and the other high pressure non-potable fire service. Here a cross connection had been ordered removed, but, instead the connecting valve had been merely closed. This cross connection valve was opened by mistake and bad water was let into the potable supply system. After unexplained conditions indicated that something was wrong nothing was done to warn consumers for a number of hours. An epidemic developed. There was negligence in failing to remove the cross connections when ordered, there was negligence in opening the old cross connection, there was negligence in failing to warn consumers when the suspicious conditions developed.

In another case the water utility has knowledge of the existence of a cross connection within a mill or factory. The cross connection is installed by and for the convenience of the mill company. Under orders of the health authorities it is so valved as to normally prevent water passing from the mill supply to the water utility system. All goes well until some person in the employ of the mill by-passes the properly valved by-pass and contaminated water reaches the system of the utility.

Has any water works operator failed to perform a legal obligation in such a case? Consider several matters in this connection. The cross connection was solely for the benefit of the mill and was on mill property and was installed and controlled by the mill. The water utility had no legal control over it. It was installed with the knowledge of the public health authorities and in accordance with their requirements. The cross connection was opened by one over whom the water utility had no control. If there is nothing more to the case than this it would be very difficult to prove negligence on the part of any water works operator.

If, however, it develops that the cross connection has been open for several months and has during all that time been putting polluted water into the system, and if it further develops that during all that period the water works operator failed to collect sys-

tem samples in the district where the supposedly closed cross connection was known to be, and examine them for evidence of contamination, then I think it possible that there was negligence. It is probable that a reasonable man, a good water works operator, would think he had a legal obligation to police his own distribution system in the neighborhood on the off chance that some mill hand might open the by-pass and cause serious damage.

The legal obligation would probably be different if the existence of the cross connection were absolutely unknown to the water works operator. In such a case there would be little, if any, reason to think that system samples should be collected in that particular section. Water works practice probably indicates that, as a reasonable man, a good operator should collect system samples more frequently in regions where known conditions indicate potential dangers, but only representative samples where no known danger spots exist.

Unjustifiable Obligations Recently Expected

This matter is mentioned because of a tendency on the part of public health authorities in some states (not Pennsylvania) to attempt to impose on water utilities what appear to be unjustifiable obligations. These authorities, knowing that cross connections are hazards, even though sealed and valved, and knowing that faulty domestic plumbing may cause localized contamination through back-siphonage, and knowing that some consumers have private well supplies of doubtful quality, are seeking to impose on water works operators the obligation of policing the premises and of inspecting the plumbing of all of the consumers attached to the lines of the water utility.

Such an obligation ought not to be assumed. The water utility probably has no legal right to make the inspection and it certainly has neither the money nor the ability required to make the original exhaustive and complete surveys, thereafter, periodic inspection at frequent intervals, which alone could give real protection. By once assuming such an unjust obligation the water works operator may possibly find one day that he is being held negligent in failing to do thoroughly that which he had unwisely undertaken to do. Good water works practice certainly indicates that it is better to do well that which water works operators have the legal obligation to do—police their own systems and facilities—than to raise a false sense of security by half doing that which they have no legal obligation to do.

FUME TRAP FOR DIESEL AND OTHER INTERNAL COMBUSTION ENGINES

By DON C. CALDERWOOD

Engineer, Pennichuck Water Works Co., Nashua, N. H.

IN THE engine rooms which house Diesel engines there is usually a problem of fumes, in some cases to such an extent that even with all the windows open these fumes cause smarting of the eyes and throat irritation. These fumes, for the most part, originate in the crankcase of the engine and usually find their way into the engine room through the crankcase breather pipe. This problem is particularly acute in installations which have worn or stuck piston rings because the highly compressed vapors in the cylinders blow by the rings, producing a back pressure in the crankcase. This back pressure, in turn, forces the oil vapor and fumes out through the breather pipe.

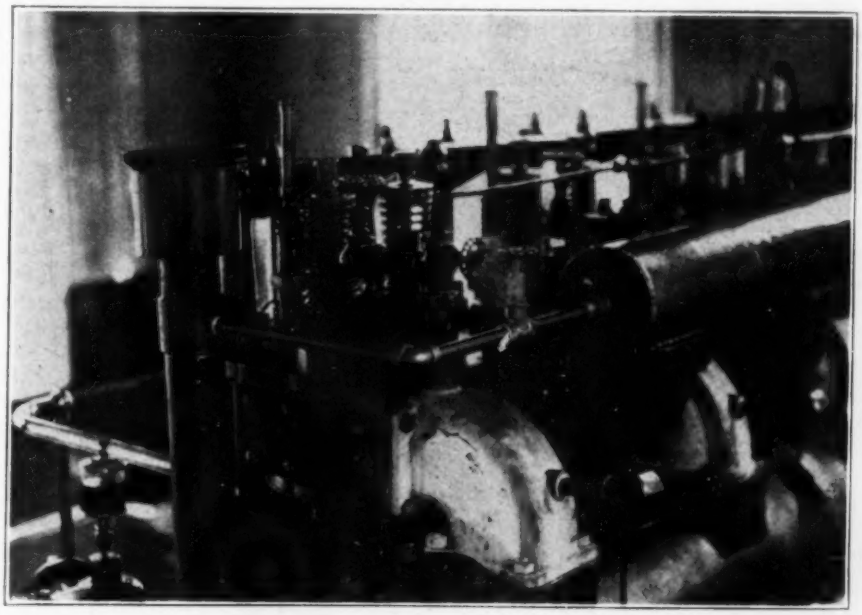
All this trouble can be eliminated by a simple piping job. Drill and tap both the air-intake manifold and the breather pipe for ½ inch pipe. In many installations it makes a much easier and better looking connection if the breather pipe is extended so that both connections can be made at the same level. Connect with a ½ inch pipe, putting a gate valve in the line, as shown in the accompanying picture.

After making the piping changes, start the engine, first *making sure that the ½ inch valve in the new connection is closed.* When the engine is well warmed up, open the gate valve slowly until the suction obtained through the connection to the intake manifold overcomes the back pressure in the crankcase. A simple way to determine when this pressure is equalized is to blow smoke by the end of the breather pipe; if the smoke is slowly forced away from the end of the breather pipe, open the valve a little more; if the smoke is drawn into the breather pipe more than can hardly be detected, close the valve a little more. It usually takes a little patience to obtain just the right opening of the valve, so when this is obtained, tighten the packing nut on the valve with a wrench so that the vibration of the engine will not change the correct adjustment.

Caution—Considerable care should be taken in adjusting this valve opening, making doubly sure that it is not open too wide. If this valve is open more than necessary, the lubricating oil vapors in the crankcase will be drawn into the cylinders and burned as fuel; this in turn will cause high lubricating oil consumption.

With this connection you are not only freed from the fumes which formerly gave you much discomfort, but you are actually burning and obtaining power from them, but remember that as a fuel, fuel oil is always cheaper than lubricating oil, so watch the valve setting for economy sake.

This type of connection is not confined to Diesels alone since it can be used on any internal combustion engine.



Fume Take-off Line on Diesel Engine.
Suction on Crank-Case Breather Pipe from Intake Manifold Is Adjusted by Setting of Valve in the One-Half Inch Line.

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VENTURI METERS

Metering the Flow of Water, Sewage, Sludge, or Air through Main Pipe Lines.

TYPE M, FLO-WATCH AND CHRONOFLO INSTRUMENTS

Metering the Flow of Water, Sewage, Sludge, Gas, or Air through Medium Sized and Small Lines, Open Channels, etc.

VENTURI CONTROLLERS

Effluent Rate, Wash Rate, Raw Sewage and Return Sewage.

FILTER GAUGES

Loss of Head, Rate of Flow, and Sand Expansion.

LIQUID LEVEL GAUGES

Settling Tanks, Filters, Clear Wells, Wash Tanks, Reservoirs, etc.

RATIO GAUGES

Air/Sludge and Return Sludge/Sewage.

KENNISON NOZZLES

Metering Open Flow of Sewage, Sludge and Trade Wastes.

CHRONOFLO TELEMETERS AND CONTROLLERS

Flow, Liquid Level, Pressure, Temperature, and Chemical Feed Proportioning.

TOLEDO-CHRONOFLO CONVEYOR WEIGH METERS

Weighing Sludge Cake in transit.

VENTURI TUBES

Fig. 1—Herschel Standard Venturi Tube

Fig. 2—VTS4 Venturi Tube

The Venturi Meter is recognized as the standard for measuring the flow of water, sewage and air in main pipe lines. It consists of the Venturi Tube (Fig. 1 and 2) installed in pipe line, and the Register-Indicator-Recorder or other instruments connected to the Tube by two small pressure pipes. The proportions and length of the Herschel Standard Venturi Tubes were selected by the inventor from extensive experimentation and are designed for a minimum pressure loss. This usually has a definite economic value since it lowers pumping costs. The VTS4 Venturi Tubes are shorter, somewhat lower in price, but throats are not as interchangeable and pressure loss is somewhat greater. Bulletin 143-A.

KENNISON NOZZLES

Accurately measure flow through partially filled pipes and open channels where there is wide range in flow rates. This device is particularly successful on measurement of raw sewage, sludge and trade waste; available in size 6" to 36"; used with instruments shown below. Bulletin 334.

Fig. 3—Kennison Nozzle for Open Flow

TYPE M REGISTER-INDICATOR-RECORDER

A popular instrument having the advantage of unusual sturdiness, durability, and accuracy; furnishes three distinct kinds of information: an indication of the momentary flow through the Venturi Tube; a permanent record of this rate shown upon a 12" circular chart; the total quantity on a 3½" counter dial; all dials graduated in direct reading units for the particular Venturi Tube with which it is to be used. Bulletin 324.

Fig. 4—Type M Register-Indicator-Recorder

FLO-WATCH

A small, medium-priced mechanical instrument universally applicable for use with Venturi Tubes, Nozzles, Orifice Plates, and Weirs; available in a variety of mountings and dial combinations. Bulletin 318-A.

Fig. 5—Flo-Watch Totalizer-Indicator-Recorder

BAROMETRIC MERCURY MANOMETER, MODEL MAB

is a simple, yet accurate, flow rate indicator with scale graduated directly in flow units; used with any type differential producer. Bulletin 343.

VENTURI FILTER CONTROLLER

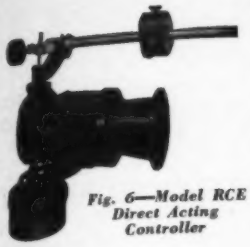

Fig. 6—Model RCE Direct Acting Controller

Since Builders manufactured the first Venturi Filter Controller many years ago, Venturi Controllers have become standard equipment in filtration plants. Several types of controllers are offered, each type designed to serve particular conditions, automatically maintaining constant flow rate through the filter bed.

THE MODEL RCE DIRECT ACTING CONTROLLER

(Fig. 6) Features smooth, unwavering control; low loss of head; sturdy balanced valve; compact design; powerful "floating piston" actuation and exclusive molded tapered piston seal. All rotating bearings of the Model RCE Controller are anti-friction bearings. Bulletin 321-A.

THE MODELS RCA AND RCB CONTROLLERS

Are hydraulically operated. Model RCA has a control valve of the gate type with specially shaped port; Model RCB has a two-butterfly valve and is used on larger effluent lines. Bulletin 325.

WASH WATER CONTROLLERS, MANUAL MASTER CONTROLLERS AND CLEARWELL MASTER CONTROLLERS also are available—information on request.

FILTER GAUGES

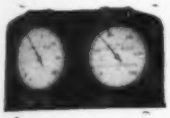

Fig. 7—Rate of Flow and Loss of Head Gauge

Builders Filter Gauges are the result of nearly a half century's experience in designing and manufacturing such instruments for hundreds of plants. Reduced to simplest mechanical elements, these gauges are styled and finished to enhance the attractiveness of modern filtration plant interiors. Bulletin 329.

RATE OF FLOW AND LOSS OF HEAD GAUGES are usually mounted on the operating table convenient to valve controls, but can be mounted on self-supporting floor stands where desirable. The indicator and chart display information gathered by the accurate, dependable Builders Diaphragm Pendulum Units which have earned emphatic approval of water works engineers after more than a decade of service under all sorts of conditions.

WATER LEVEL GAUGES are used for indicating and/or recording water level in basins, tanks and reservoirs, operated by spherical copper float in a pipe or well. Indicator dials and charts are graduated to read in feet of depth, elevation or other units.

Fig. 8—Large Dial Gauge

BUILDERS LARGE DIAL ILLUMINATED GAUGES, available in 24" and 30" sizes with single or double faces for wall or ceiling mounting, are commonly used in water works to make readings visible to the operator from a distance. Concealed double hinges, a patented feature, allow access to the mechanism without removal from mounting. Indirect white gas-tube illumination gives a pleasing soft glow uniformly around entire dial circumference.

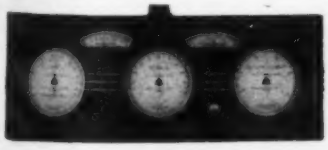

Fig. 9—Five-Dial Ratio Gauge

RATIO INDICATING GAUGES are especially useful in sewage plant operation and enable operator to maintain predetermined ratio of flow rates between air/sewage, air/sludge, etc.

CHRONOFLO TELEMETERS

Since their introduction a decade ago, Chronoflo Telemeters have found broad application in water and sewage plant service in bringing to a central operating point, from widely scattered locations, accurate records of flow, (Fig. 11) level, (Fig. 12) pressure, temperature, gate position, and weight. Chronoflo Transmitters are electrically connected by a simple two-wire circuit to Chronoflo Receiving Instruments. Automatic proportional control of Chemical Feeders in step with rate of flow is accomplished by a simple attachment to a standard Chronoflo Transmitter.

Fig. 10—Chronoflo Receiver

DISTANT METERING

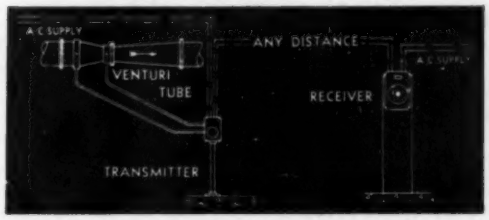

Fig. 11—Flow through a Venturi Tube transmitted to Chronoflo Recorder at distant point.

TANK LEVEL AND PUMP CONTROL

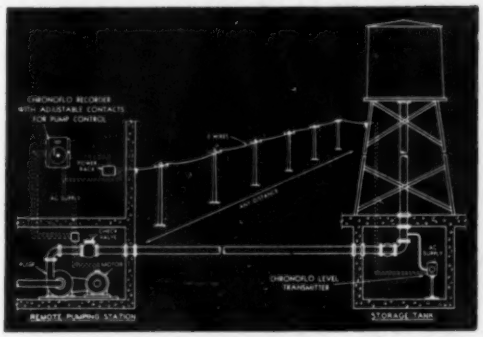

Fig. 12—Level in distant elevated tank is recorded and pump is controlled by Chronoflo.

KENNISON NOZZLE METER

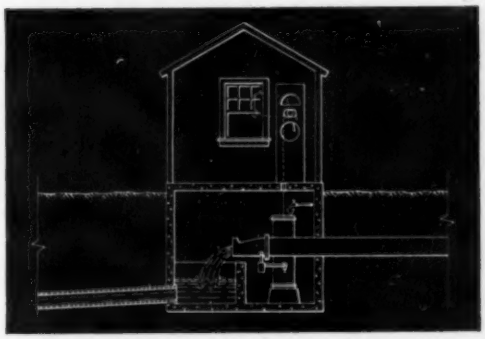

Fig. 13—Kennison Nozzle and Totalizer Indicator Recorder meter gravity flow.

AUTOMATIC SLUDGE WEIGHING

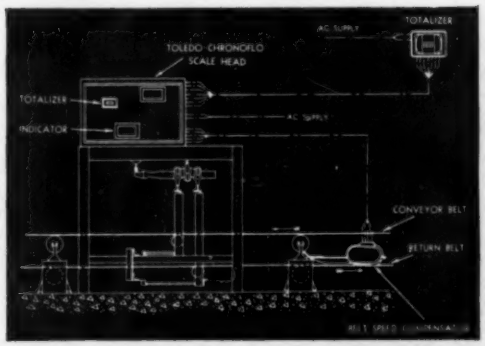

Fig. 14—Toledo Chronoflo Conveyor Weigh Meter. Weigh-metering sludge in transit.

BAILEY METER COMPANY

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BAILEY METER COMPANY LIMITED, Montreal, Canada

METERS, GAGES and CONTROLLERS for SEWAGE TREATMENT and WATER SUPPLY

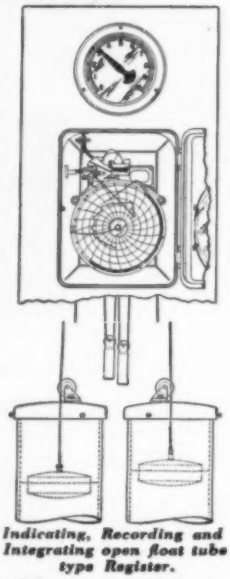
STANDARD BAILEY REGISTERS

Open Float Type Meters—The flow of sewage, sludge, dirty water or other liquids in pipe lines is accurately measured by the Bailey Float Type Meter using a Venturi Tube, flow nozzle or orifice as the primary producing device.

This meter is of the open float tube type with differential gearing and cam designed so that the register operates in direct proportion to the rate of flow.

Standard Bailey indicating, recording and integrating instruments are used; charts being 12" in diameter and uniformly graduated. These instruments may be either wall or panel mounted and may be furnished on self-supporting panels if desired.

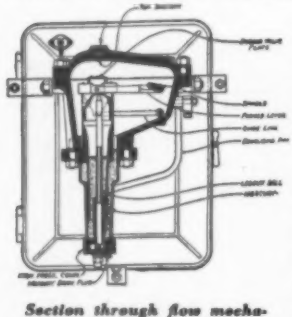
Bailey float type meters are simple, sturdy, neat-appearing and extremely flexible. Capacities may be changed by simple adjustments within the register and remote instruments can be operated from the main register if desired.



Indicating, Recording and Integrating open float tube type Register.

Bailey Flume Meters—Surprising low head losses result from the measurement of water or sewage in open channels when Bailey Flume Meters are used. These simple self-cleaning meters indicate, record and integrate on standard Bailey registers. Instruments may be placed in remote locations by the addition of the Bailey Synchro-Meter transmission system.

Bailey Weir Meter—Highly accurate results in the measurement of sewage or water flowing in open channels are obtained by the use of the Bailey Weir Meter.



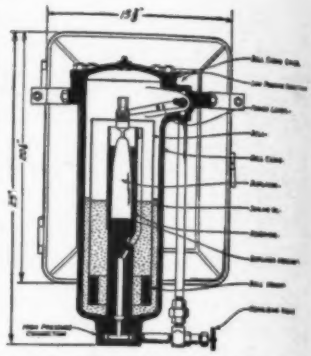
Section through flow mechanism of Ledoux Bell type Register.

Complete flexibility in the location of the standard Bailey registers of this meter may be provided by the Bailey Synchro-Meter transmission system.

Bailey Fluid Meter—The flow of steam, liquids and gases in pipe lines at high or low pressures can be accurately measured by the Bailey Fluid Meter. A Venturi Tube, flow nozzle, or orifice is used as the differential producing device and the meter indicates, records and integrates on the standard Bailey register previously described. Remote recorders may be provided by Bailey Synchro-Meter transmission which operates electrically on alternating current.

In addition to the rate of flow, this meter may also record pressure, temperature or liquid level on the same chart.

Described in bulletin No. 301A.



Section through flow mechanism of Air Meter

Air Meters—These meters measure Air Flow in main lines and in individual lines to aeration tanks.

The register is similar in appearance to the Ledoux bell type, and the flow mechanism is designed to operate on a maximum differential pressure of 8-in. of water. *Described in bulletin No.* 301A.

Remote Registers—Bailey Telemetering systems make it possible to operate remote indicating, recording or integrating registers, which may be installed at a distance from the direct connected unit. These registers may measure flow in individual lines, total flow, liquid level, pressure and other factors.

Venturi Tubes—Standard Bailey Designs include a complete range of Venturi tubes and other primary elements suited to the measurement of sewage, sludge and water. The selection of a suitable primary element is governed by such factors as capacity required, type of flanges, pressure loss allowable and character of fluid to be metered.

Controllers — Bailey Controllers utilize standard Bailey Meters and Recorders as the basic measurement source for the automatic control of factors, such as flow, ratio, pressure and liquid level. They are operated by compressed air at approximately 35 lbs. pressure and match perfectly with other Bailey gages and registers.

Bailey control is fully automatic, dependable and exceptionally flexible.

Bailey Recorder—Controller.

Bailey Registers measuring Sewage, Sludge and Air in an operating gallery at Easterly Sewage Treatment Works, Cleveland, Ohio.

MAIN-LINE METERING OF WATER, SEWAGE AND SLUDGE

By ROBERT T. REGESTER
Consulting Engineer, Baltimore, Md.

AN accurate and convenient means for metering the flow of water in main pipe lines presented an unsolved problem in early American hydraulic and water supply practice. It was not until 1887 that Clemens Herschel, eminent New England engineer, conceived the idea of applying the Venturi principle as a practical method of flow measurement. After conducting elaborate experiments, he invented and successfully calibrated a compound conical tube which he named the "Venturi meter." In 1891 the meter was first installed by the East Jersey Water Company. Its success was immediate and marked a notable contribution to hydraulic engineering. Twelve years later, the first Venturi meter for the measurement of sewage was installed in a large discharge pipe at the Ward Street Pumping Station of the Boston sewerage system. This installation was also successful and continues in operation today.

Since these first applications, continuous developments and improvements have been made in Venturi metering, particularly with regard to automatic registering and recording instruments. Today Venturi meters and their related devices are used throughout the world in both water works and sewerage systems for a variety of purposes. They are recognized as invaluable aids to the efficient operation and control of modern water purification plants and sewage treatment works. Although other metering elements are available, the Venturi meter is the universal standard for the measurement of water, sewage and sludge flowing through main pipe lines.

Venturi Tubes

A standard Venturi tube, as shown in Figure 1, comprises a cylindrical inlet, a converging inlet cone, an intermediate "throat" section and a diverging outlet cone. The inlet cone has a rather

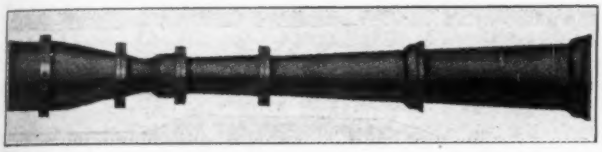


Fig. 1—The Herschel Standard Venturi Tube

steep taper while the outlet cone tapers more gradually. The interior passageway of the tube is entirely unobstructed. The sections of these tubes are usually made of cast iron with throat part bronze-lined to resist corrosion. The inlet and outlet cones are occasionally constructed of either reinforced concrete or steel plates. At both the inlet and the throat of each tube, an annular pressure chamber communicates with the interior by means of numerous small and equally-spaced vent holes. These annual chambers are basically important features of Venturi tubes. The essential purpose of each chamber is to average the pressure head at several points around the tube's circumference, thus avoiding the inaccuracies otherwise introduced by using a single-vent piezometer.

The favorable hydraulic properties of the standard Venturi tube are unequalled by any other type of metering device for main pipe lines. If piezometers are inserted along a standard Venturi tube, the hydraulic grade line will follow the curve as illustrated in Fig. 2. The velocity of flow rapidly accelerates from the inlet to the throat, and thereafter gradually decelerates through the outlet cone. Accordingly the pressure head which is greatest at the inlet end rapidly decreases to the throat where it is least. This difference in pressure bears a definite relation to the velocity of flow and therefore, the quantitative rate of flow. This function varies approximately as the square of the velocity in the throat. It should be particularly noted that the pressure is gradually regained as the velocity decreases in the outlet cone, until at the outlet end nearly all of the original pressure head has been restored. The overall pressure drop, or "friction loss," between the inlet and outlet ends is relatively small for normal rates of discharge, and for low rates it is negligible.

The size of a Venturi tube is expressed by the diameter of the inlet and outlet ends, in inches, which usually is the same nominal diameter as the pipe line for which the tube is intended. The standard tube of Herschel proportions has an average length of about nine inlet diameters, but the exact length depends upon the throat diameter. For installations where the conditions are favorable, shorter and somewhat less costly Venturi tubes are available. In general, these are similar in construction to the standard tubes, but have outlet cones of sharper taper with consequent greater friction loss. Certain special designs of tubes are also made, such as elliptical, constant-acceleration and flat-invert (or eccentric type). In instances where low points cannot be readily drained, or where overhead clearances are very limited, the flat-invert tube may be desirable. However, such tubes are considerably more costly than standard concentric tubes, which experience has demonstrated to be most suitable for normal installations.

For the measurement of sewage and sludge, Venturi tubes require certain special appurtenances. At the inlet and throat pressure chambers, vent-cleaning valves are necessary so that, at intervals, the vents can be cleaned of deposits and the pressure chambers flushed. An individual hand valve is often provided for each vent. However, a recent device (Fig. 3) is available for simultaneously actuating all of the vent-cleaning valves by the operation of a single water- or air-pressure supply valve. Hand holes near the inlet and the throat are useful for an occasional inspection of the interior surface of a tube. In cases where the sewage contains corrosive industrial wastes, a special split-flange section of tube can be provided to expose the entire throat part for examination and cleaning.

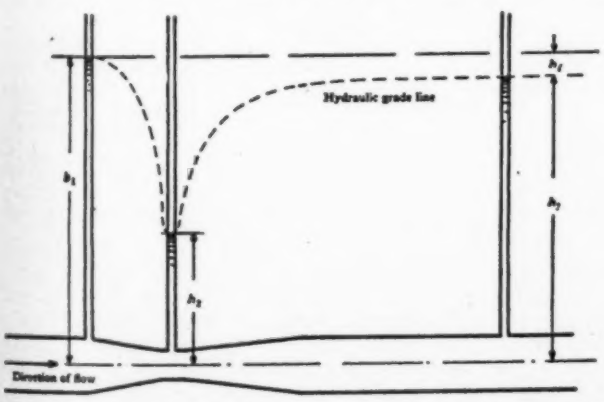


Fig. 2—Hydraulic Grade Line for Flow Through a Venturi Tube

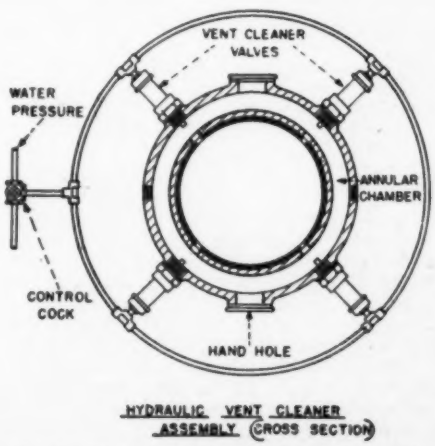


Fig. 3—Hydraulic Vent Cleaning Assembly for Simultaneous Operation

Other Types of Meters

Orifices and Nozzles

Among other types of meters available for main pipe lines are orifices and flow nozzles. Orifices can be obtained in several forms, the most familiar of which is a circular opening in a flat plate clamped between a pair of flanges in the pipe line. The hole of the orifice may be either concentric or eccentric in the flat-plate type. Piezometer connections are made on each side of the orifice plate by tapping two small tubes into the main pipe line. The differential pressure between the inlet and outlet sides of the plate is used to actuate the metering instrument. Orifice plate assemblies with annual pressure chambers, tapped for piezometer connections, are available.

The hydraulic grade line for a plate orifice is shown in Fig. 4. With flow through the main pipe, the pressure head drops abruptly at the orifice and continues to decrease slightly opposite the plane of greatest contraction just downstream from the plate. Beyond this plane the pressure then increases with partial recovery of the original pressure head. Because of the plate projection inside the pipe considerable turbulence results; hence the overall

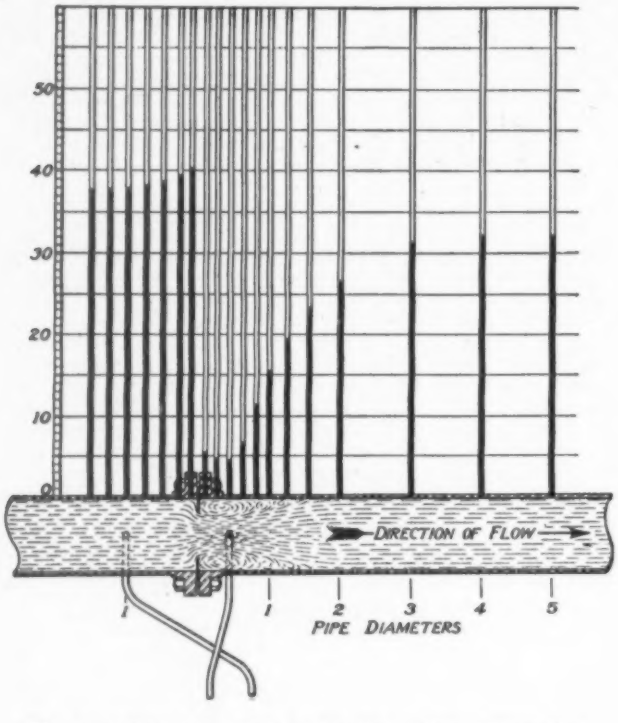


Fig. 4—Hydraulic Grade Line for Flow Through a Concrete Plate Orifice

friction loss for a given ratio of orifice and pipe diameters is much greater than for a Venturi tube having the same ratio of throat and inlet diameters.

If used for the measurement of sewage and sludge, plain orifice meters may be subject to inaccuracies resulting from erosion of the edge and accumulation of solid matter at the projection. Certain specially shaped orifices, or so-called "flow nozzles," resembling Venturi tubes can be furnished to overcome some of the disadvantages of the plate orifice.

The Kennison Nozzle

The Kennison open-flow nozzle is suitable for measuring flows of sewage, industrial wastes and sludge in partially filled pipes and open channels. This nozzle is bolted to the outlet end of a main pipe line with free discharge. The design utilizes the inlet depth produced by a specially shaped outlet for the rate-of-flow function which varies directly with the head. At the inlet of the nozzle, a connection is made to a float tube for operating the metering instrument, Fig. 5. Kennison nozzles are made in inlet sizes varying from 6 in. to 36 in. diameter. Another type of nozzle for partly filled pipes utilizes the discharge-angle relation, produced by a vane which receives the discharge impact, as the rate-of-flow function. This latter nozzle (Schofield) has a parabolic outlet.

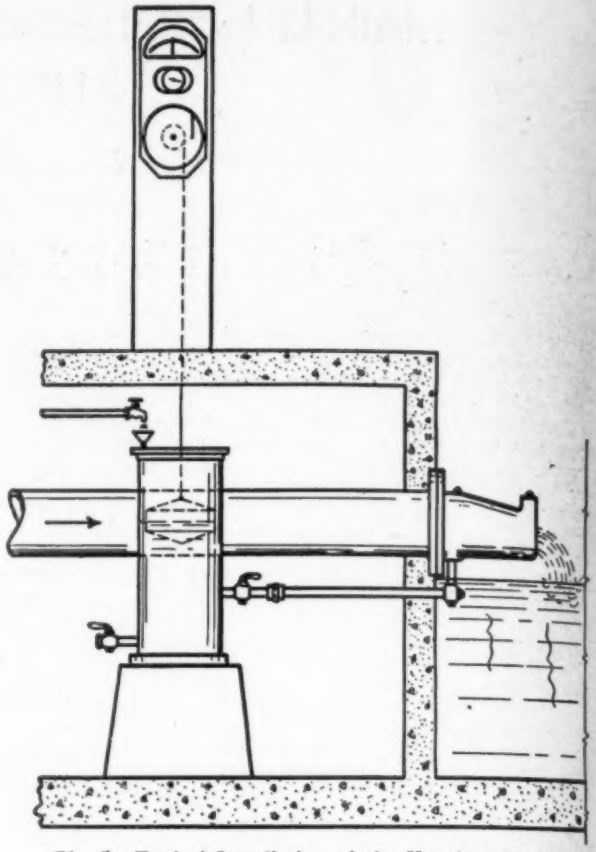


Fig. 5—Typical Installation of the Kennison Nozzle

The Parshall Flume

For the measurement of sewage flows in open channels, the Parshall flume is now extensively used. This Venturi shaped flume usually operates as a free-flow device and therefore requires the use of a single pressure head to accurately determine the discharge rate. The flume was originally developed and is widely used in the West for irrigation purposes. The first important installation for measuring sewage was at Providence, R. I., in 1931, where a large flume having a capacity of 120 M.g.d. with throat width of 10 ft. (Fig. 6) meters the effluent from the sewage treatment plant. An important characteristic of the Parshall flume is the relatively small loss of head, which is about one-fourth that of the standard weir for free flows. This flume is adaptable for both large and small plants and has been calibrated for a variety of sizes and corresponding capacities. A pipe connection is made on the tapering inlet side of the flume for the float actuation of a metering instrument.

Discharge Coefficients and Friction Losses

With any type of meter for main pipe lines, the accuracy of measurements must be supported by exact knowledge of the discharge coefficient and its relation to the size, ratio and other characteristics of the respective type. The accuracy of the Venturi meter has been established through numerous carefully conducted calibration tests by hydraulic laboratories and prominent manufacturers. Such tests have demonstrated that the high initial accuracy of the Venturi meter remains unimpaired during years of continuous service. Coefficient curves for standard Venturi tubes (as made by Builders Iron Foundry and the Simplex Valve & Meter Co.) are available in the A. S. M. E. —Fluid Meters Research Publication, Part I, 1937. In addition thereto, various types of upstream disturbances have been analyzed with regard to Venturi tubes and corrective vanes have been studied by Prof. W. S. Pardoe (Trans. A. S. M. E.—Nov., 1936, and Nov., 1937). Also, a valuable study of the proper application of piezometer connections to metering devices was made by Messrs. Allen and Hooper (Trans. A. S. M. E.—1931) as a further contribution toward meter accuracy.

The overall friction loss produced by a differential metering device in main pipe lines is frequently of economic importance. Such losses may substantially increase annual pumping costs, or may materially decrease the gravity head which is available for

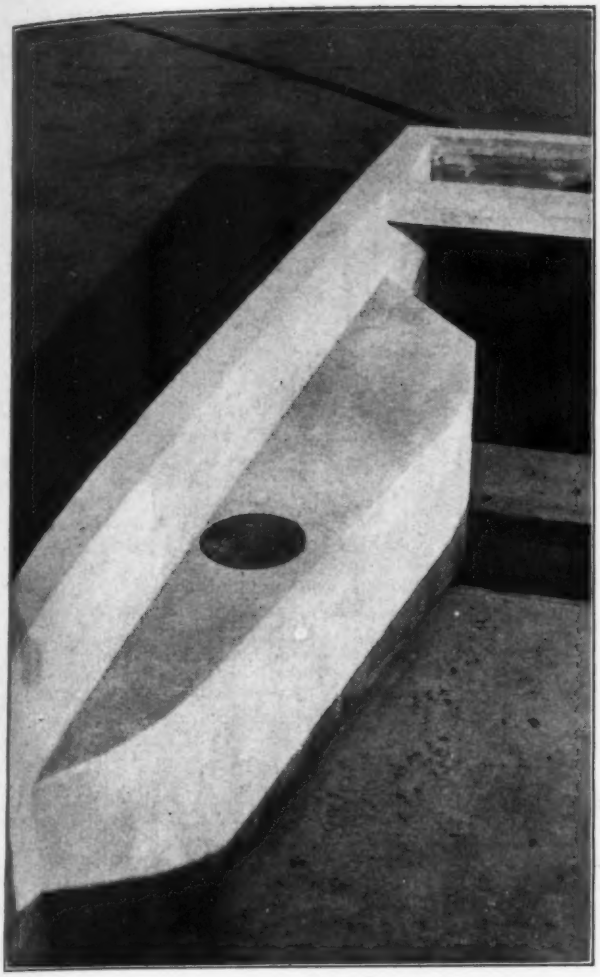


Fig. 6—One-Half of the Parshall Flume, Looking Downstream to Throat Section—Providence, R. I.

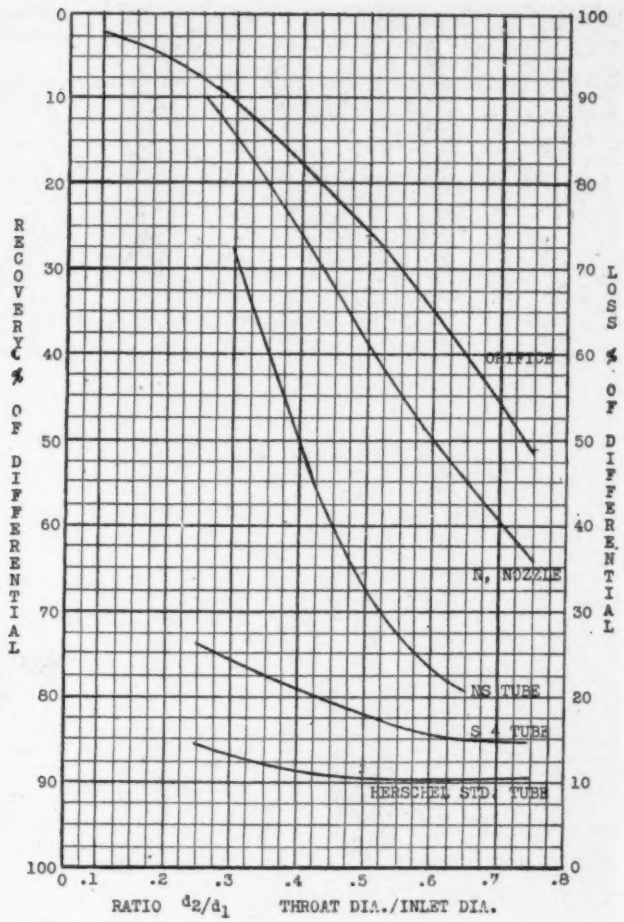


Fig 7—Recovery Characteristics and Friction Losses of Various Differential Producers

For Figs. 8 and 9, see next page.

other essential purposes in both water purification and sewage treatment plants. This latter condition may involve greater construction costs due to the lowering of structures to meet the resulting hydraulic grade lines. In either case, a small initial saving in the price of an unsuitable meter may be insignificant in comparsison with the ultimate cost incurred by excessive fraction loss. Accordingly, that metering device in which the recovery of inlet pressure head is the greatest will most likely prove to be the most economical selection.

The accompanying diagram, Fig. 7, strikingly presents a comparison of the recovery characteristics and friction losses for a standard Venturi tube of Herschel proportions, a short Venturi (S4) tube, two types of flow nozzles (NS and N) and an orifice plate. These data are expressed thereon as precentages of the differential head for various ratios of throat and inlet diameters. For the frequently used ratio—0.5, it should be noted particularly that the corresponding friction loss for an orifice is about seven times the loss for a Herschel standard tube.

Herschel standard Venturi tubes have a fraction loss of only 10% to 15% of the differential head for a ratio of 0.25 to 0.75—throat to inlet diameter. In comparison, the fraction loss for orifices is much greater and varies from 49% to 92% of the differential for the same ratio range of orifice opening to pipe diameter.

Venturi Metering Instruments

A variety of instruments for the measurement of water and sewage in connection with Venturi tubes and other differential metering devices is available. Each type is actuated by the differential head, either by direct connection or by some medium of transmission such as air or electricity. Several types of instruments are illustrated in Fig. 8 and 9. The mechanism of one prominent type is shown in Fig. 10. At the rear of the register two large mercury wells, connected at the bottom to form a U-tube, receive the differential pressure from the Venturi

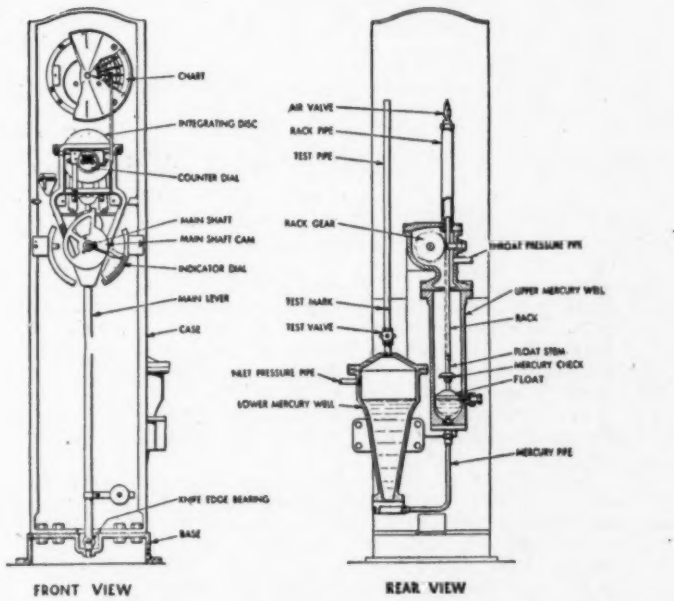


Fig. 10—One Example of the Pressure Chamber Type of Register Mechanism, with Rack and Gear Transmission of the Float Movement

tube through small pipes from the inlet and the throat. One of the mercury columns supports a solid metal float of large diameter, which is responsive to minute variations in mercury levels. Through a positive rack and gear transmission, the float

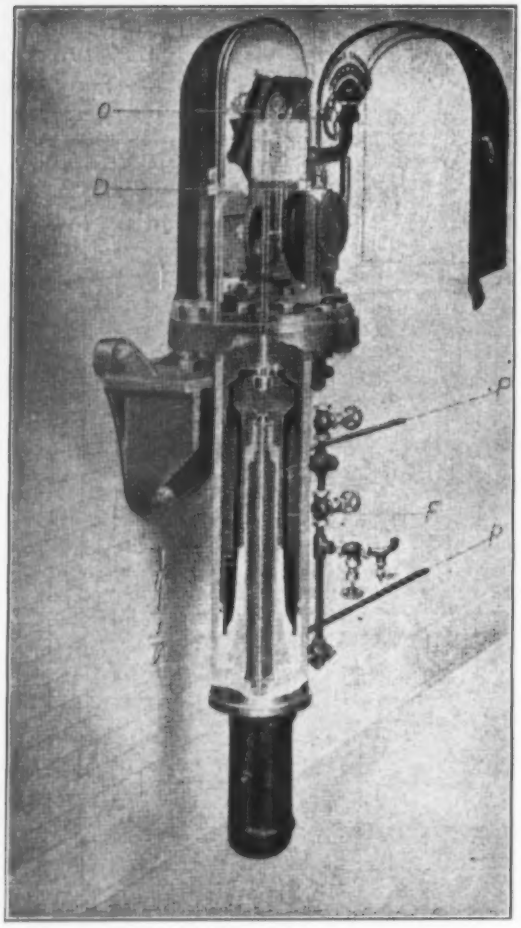


Fig. 8—Pressure Chamber Type of Instrument Using Mercury Sealed Bell (Courtesy of Simplex Valve & Meter Co.)

For Fig. 10, see preceding page.

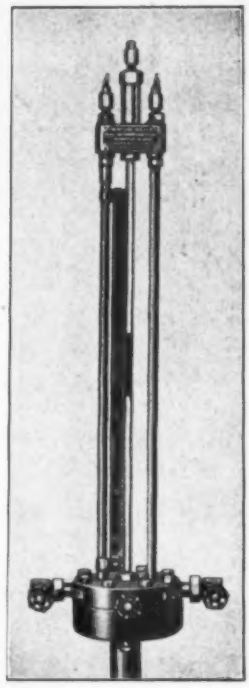


Fig. 11—Portable Flow-Rate Indicating Instrument of the Barometric Type

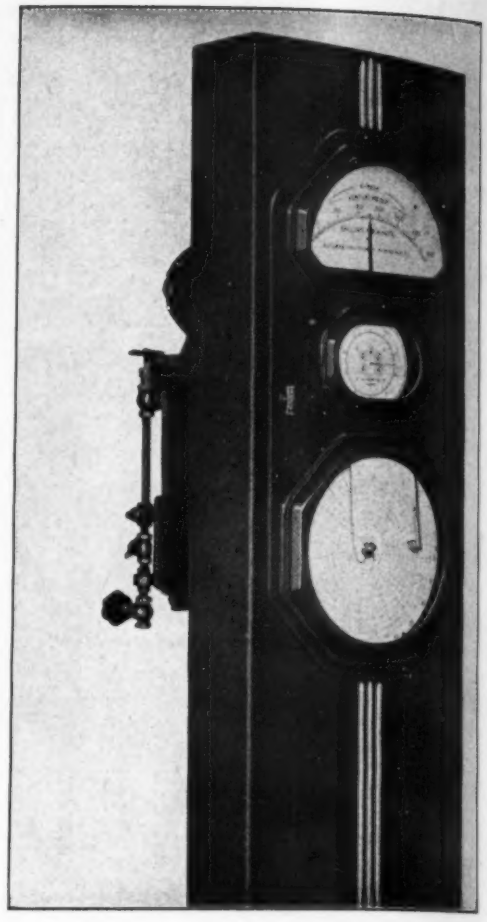


Fig. 9—Modern Register-Indicator-Recorder, with Pair of U-Tube Mercury Wells (Courtesy of Builders Iron Foundry)

movement establishes the position of the rate-of-flow indicating hand, the rate recording chart pen and the driving roller of the motor-driven totalizer. These are respectively the upper, lower and middle dials (Fig. 9).

A simple mechanical instrument, suitable for main pipes in small plants and for less important pipes in large plants, is very similar to the instrument shown in Fig. 13. This instrument can be used with either Venturi tubes or orifices for the measurement of water, sewage, sludge, air and other fluids. Principal features of this device are compact design, gear-driven integrator and universal mounting for floor, wall or panel.

A portable and sturdy flow-rate indicating instrument of the barometric type is shown in Fig. 11. The rate scale, 22 in. long, can be graduated to read directly in units of flow. The slightest change in rate through the Venturi tube, or other differential producer, will cause an immediate and relatively large response in the vertical movement of the mercury column within the single glass tube. In addition to this instrument, several types of manometers can be obtained for a variety of purposes. A double-tube type is especially suitable for general testing work. Graduations can be either in inches of deflection, or directly in rates of flow.

Where the conditions of installation make the use of mechanically actuated instruments impracticable, electrically-operated transmitters with receiving instruments can be employed for remote metering indications and recordings. Numerous types or systems have been developed such as time impulse, stepped resistance, self-synchronous motor pairs and others.

The time impulse system is used with Chronoflo transmitter and receiver instruments, Fig. 12 and 13. The transmitter receives the differential pressure, and is usually installed close to the Venturi tube or other differential device. It contains a mercury float, a synchronous motor-driven mechanism and a magnetic mercury switch. These elements are so interconnected that for a portion of each cycle (¼ to 1 minute), varying in duration in exact proportion to the rate of flow, electrical "time impulses" are sent to the distant receiving instrument. The latter, through motor-driven magnetic clutch elements, translates these impulses into flow units on the dial and chart.

Weather-proof instruments for installation out of doors are readily available with substantial weather-proof metal housings.

Metering instruments are logical sources of signal and control actions as related to flow rates. Lights, sound apparatus, power relay switches and other electrical elements can be readily actuated by such instruments at relatively small cost.

Methods of Installation

Two simple methods of installing Venturi tubes and instruments for the measurement of water are shown—Fig. 14. That for medium and high heads is on the left, and the method for low heads on the right. When the pressure is ten pounds or

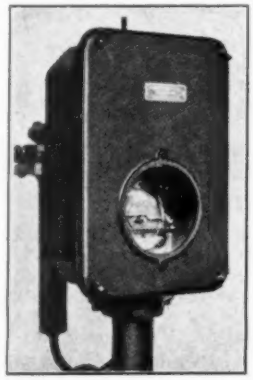


Fig. 12—Transmitting Unit

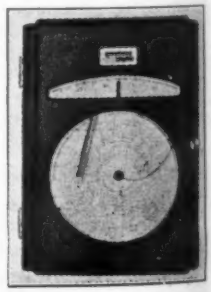


Fig. 13—Receiving Unit

Chronoflo Time-Impulse Instruments for Remote Metering (Courtesy of Builders Iron Foundry)

more at the floor where the instrument is located, two small pressure pipes—one from the inlet and the other from the throat of the tube—form a direct connection. These pipes can be several hundred feet in length. Where the acting hydraulic head is low (e.g. raw water supply to filter beds) the usual mercury wells at the back of the registering instrument are

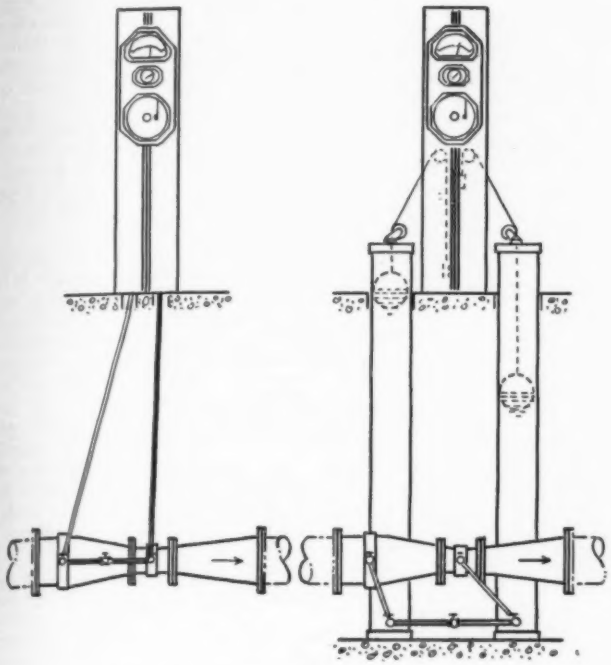


Fig. 14—Venturi Meter Installations
Left—For Medium and High Heads
Right—With Float Tubes for Low Heads

removed and vertical inlet and throat float tubes are substituted. Cables from these floats lead to a differential actuating mechanism at the back of the instrument.

Other types of installation require the mercury wells to be placed at a low elevation with a cable connection to the register above. With any of these types for the measurement of sewage and sludge, provision must be made for seals to prevent deposits from reaching the registering instrument through pressure connections, or for proper flushing with clean water. Such flushing may be either continuous or manually regulated, as the requirements dictate.

Air Relay System

The use of compressed air as a medium for the transmission of the inlet and throat pressures of a Venturi tube, or other differential producer, to a distant recording instrument is frequently advantageous. One type of "air relay system" employs two diaphragm units, one directly connected to the inlet and the other to the throat of the Venturi tube. Each unit consists (Fig. 15) of a hollow chamber (C) which is divided into two compartments by a solid rubber and fabric diaphragm (D). The inner side of the diaphragm is subjected to the liquid pressure from the tube; the outer side receives an external air pressure to balance the liquid pressure on the inner side. Air is continually vented through a throttled needle valve (N) attached to the diaphragm unit. Two small pipes, one from the inlet and the other from the throat relay unit, are connected from the outer compartments to the usual mercury wells at the rear of the registering instrument. The transmitted air pressures are exactly equal, respectively, to the actual inlet and throat pressure heads in the Venturi tube.

This type of unit forms a seal between the tube and the instrument, which is especially important in metering sewage and sludge. In the measurement of sludge, unless it is "thin," it is necessary to provide continuous water flushing through appropriate small sight-feed orifices.

Another well known type of air relay system operates with a single air pressure which is proportional to the amount of the liquid differential pressure.

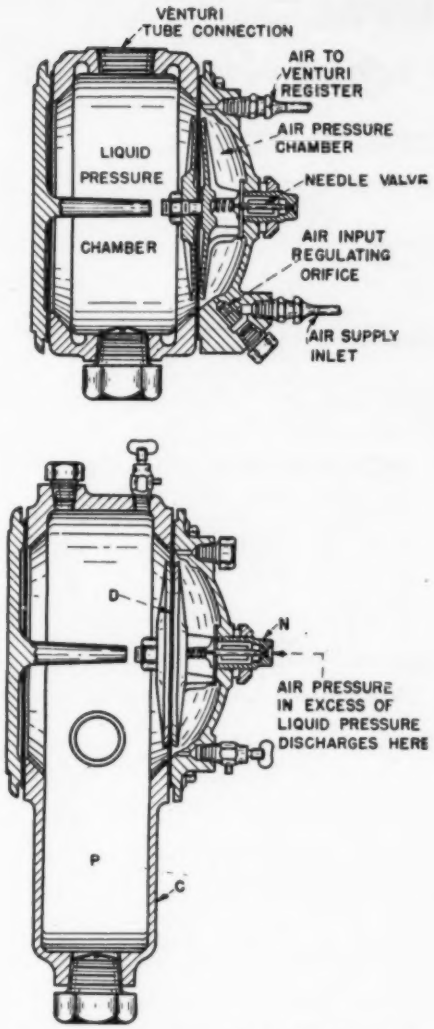


Fig. 15—Diaphragm Unit for Air-Relay System

Flow Summation

Recent developments make it possible to summarize, on a individual meters in their respective discharge pipes. It may be single instrument, the readings of several meters. For example, a water works pumping station may have several pumps with desirable to totalize these separate flow rates for purposes of accurately introducing chemicals, such as chlorine, without wastage. In this case, an electrical transmitter (such as Chronoflo) can be attached to each registering instrument (Fig. 16). The impulses sent out by these transmitters go to a master unit which integrates the respective values, and then transmits the total to distant summation indicating, recording and totalizing instruments, as required.

In sewerage districts and sewage treatment plants, the summation principle can be utilized to great advantage. Sewage flows from scattered communities can be summarized and transmitted to the central or joint treatment plant for the guidance of the operator, and for the allocation of operating charges. Likewise, flow divisions within a large sewage plant can be summarized for control purposes.

Means can also be provided to give the difference in readings for two meters, or the difference of the combined rates of flow in groups of meters.

Special Metering Instruments

The marked trend in recent years of centralized control in water purification and sewage treatment has been accompanied by a fulfilled demand for the broader performance of main pipeline meters. Distant transmission by air or electricity to centralized panels and control tables, the ratio of one flow to another, the summation of flows to one or more central dials, the automatic

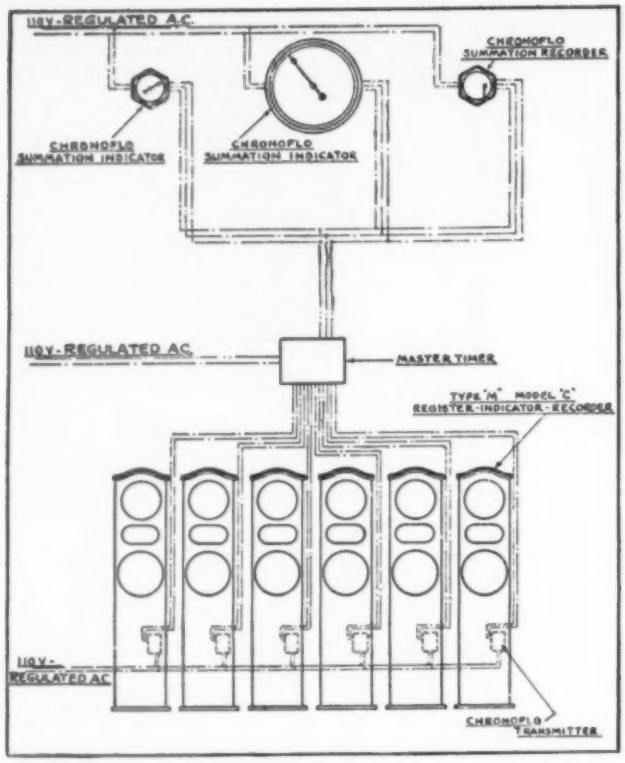


Fig. 16—Diagrammatic Arrangement of Flow Summation Instruments for Cermak Station, Chicago

controls of flows and distant pumps to maintain perdetermined levels or rates, the proportioning of chemical dosages to main flows and other functions, are examples of modern metering requirements. The design and finish of the instruments themselves have been "modernized" to harmonize with the present architectural attractiveness of plant interiors. Effective illumination has been likewise provided for single- and double-faced master indicating gauges, frequently of large diameter.

A flow and ratio gauge for each unit in a modern activiated sludge plant is illustrated, Fig. 17. There are five dials, the three largest showing (left to right) rates of air flow, sewage flow and return sludge flow to an aeration tank. The two smaller dials show (left) the ratio of air to sewage—in cu. ft. per gal., and (right) the ratio of return sludge to sewage—in per cent of sewage flow. In addition, there is an automatic control knob for pre-setting the latter ratio for any desired value. A pair of these five-dial gauges are mounted on one control table similar to those used in water filter plants.

Installation Requirements

To insure the proper application of metering equipment, specific data should always be obtained from the meter manufacturer for a particular installation. However, in general, certain standard requirements are noteworthy.

The Venturi tube should preferably be preceded by a straight length of pipe having the same diameter as the tube; this length being at least six times the tube diameter up to 24 in. and at least 12 ft. for larger sizes. Where space is limited, or there is the probability of turbulent or spiral flow ahead of the tube, straightening vanes may be required. Any kind of fitting may be placed at the outlet end of the tube. Since the centrifugal pump is almost universally used in water works and sewerage systems, pulsations in flow are rarely encountered. However, such condition may occasionally be presented and must receive special consideration. It is essential in making pressure pipe connections that they be run on a continuous grade, avoiding summits or depressions where air or silt may collect.

The Parshall flume must be set at the proper elevation with respect to the channel, preferably so that it can operate at all times under "free flow" conditions, with a limit of 95% submergence. It should be located in a reasonably straight section of channel, where the distribution of flow is fairly uniform. The flume, however, will operate satisfactorily under rather poor approach conditions. The dimensions and proportions of the flume must adhere to the established standards.

In installing the Kennison nozzle, care must be taken to provide proper approach conditions. This device should be preceded by a section of pipe at least eight diameters in length, and the water or sewage must flow smoothly from the nozzle under free discharge. Any conditions of installation which might cause a "shooting velocity" at times, should be corrected by the use of proper fittings upstream.

Orifice plates are more sensitive to approach conditions than Venturi tubes, and require a straight length of smooth pipe both upstream and downstream from the plate. For the upstream, the length required may vary from five to thirty diameters, while for the downstream length—up to eight diameters, depending upon the piping layout and the diameter ratio. Straightening vanes may be required to eliminate swirls, cross currents and eddies; their use may make it possible to shorten the necessary lengths of pipe as just mentioned.

Conclusion

Certain fundamentals of main line metering and some of the modern developments in metering equipment have been briefly discussed. Emphasis is placed upon the importance of regarding each meter installation as an engineering problem, which requires the consideration and advice of experienced manufacturers. Low cost equipment may properly serve for relatively unimportant work, but is entirely unsuitable for checking the daily performance of main units and for controlling the efficiency of treatment processes. In general, the highest grade of equipment as offered by prominent manufacturers cost only a small fraction of the total construction contract on important projects. Obiviously, the best is the wisest selection.

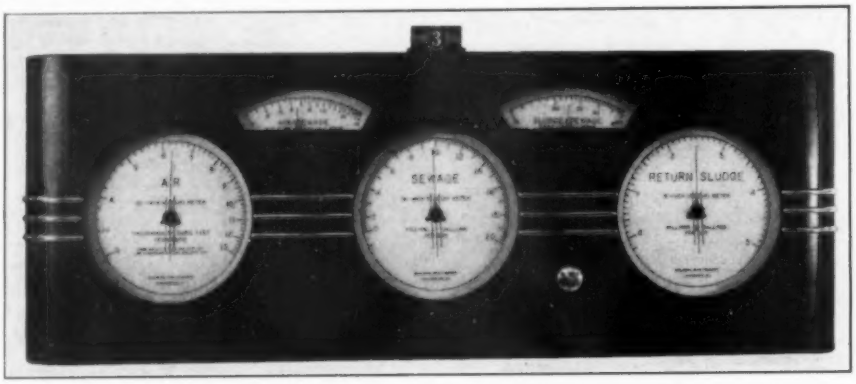


Fig. 17—Special Flow and Ratio Gauge for Modern Activated Sludge Plant, Baltimore, Md.

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Venturi Type Meters for All Services
Orifice Type Flow Meters
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Flow Indicators
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Indicating, Recording and Totalizing Meters for — Steam, Air, Gas, Water, Sewage, Sludge

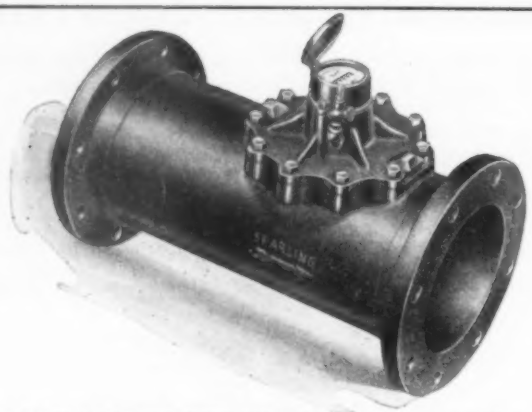
Pitot Rods and Manometers
Simplex Egg-Shaped and Impact Flume Meters
Simplex Parshall Flume and Weir Meters of the Indicating, Recording, and Totalizing Types

R. W. SPARLING

MANUFACTURER OF

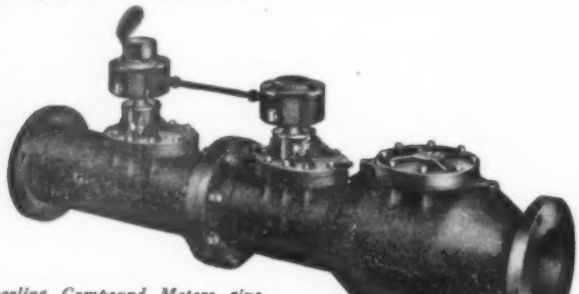
MAIN-LINE WATER MEASURING EQUIPMENT

Box 3277 Terminal Annex, LOS ANGELES 54 — 3104 S. Michigan Avenue, CHICAGO
622 Broadway, CINCINNATI — 101 Park Avenue, NEW YORK 17 — 6 Beacon Street, BOSTON



PROPELLER-TYPE METERS measure the flow in main-lines two inches and over, by the direct action of stream velocity on a propeller mounted in the pipe or tube. Sparling Main-Line Meters may be saddle-mounted on the pipe in place, or in tube sections, as shown above. Saddle-type meters, 2-inch to 72-inch; screw-tube meters, 2-inch to 6-inch; flanged tubes, 2-inch to 36-inch; bell & spigot tubes, 4-inch to 36-inch.

Compound meters, with flanged or bell & spigot ends, 6"-2" to 36"-10".



Sparling Compound Meters give accurate totalization over an even wider range of flows

Sparling Meters are guaranteed accurate within two per cent within their rated range. This, in 6-inch tube meters, for example, is from 90 to 900 GPM. The rated range for a 10"-3" Sparling Compound is 30 to 1500 GPM, with very little head pressure loss.

RECORDERS INDICATORS

The primary reading in all Sparling Main-Line Meters is *totalization*, each meter being a self-contained totalizing unit. For conversion to flow-rate, the revolutions of the propeller are transmitted to Mercury Governor type Indicator-Totalizers or Indicator-Totalizer-Recorders. Control is by flexible cable within 15 feet of the meterhead, or by electric remote control at any distance.

The Pedestal-type Recorder, shown at right, is No. 212 and charts may be for 24-hour or 7-day periods. Panel and wall mounted types are also available.

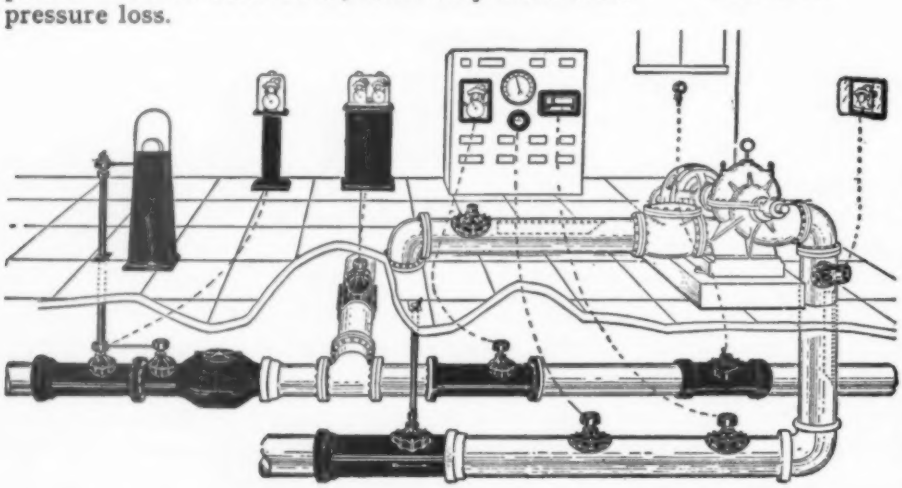
24-HOUR 7-DAY 60-DAY

Other instruments available are of a differential type with straight-reading, equal calibration, 60-day strip-roll charts. These operate electrically, at any desired distance from the transmitter mounted on the meterhead.

"Town Clock" Indicators have single or opposed 17-inch dials. The figures, lighted from within, may be read 150 feet or more away.

CONTROLS

Sparling Auto-Metered Controls include Batch Controls, Power Extensions, Chemical Feed Controls, with Variators to change the rate of feed. Also Stock Samplers; Steady-Flow Valves and Metrograph Recorders.



Typical Pumping Station Installations

Sparling Meters may be installed on the suction or discharge side of the pump, in vertical or horizontal position. Note at left of sketch, a Bell & Spigot Compound Meter with remote recorder and solid extension connecting with chlorinator. A saddle mounted meter on wood or transite pipe is also shown. For further details, see Bulletin No. 308, sent upon request.

PROPELLER-TYPE METERS

For Main-Line Metering

JAMES M. MONTGOMERY, Consulting Engineer*
Los Angeles, Calif.

THE principle of the current meter has been used as a primary metering element for the measurement of stream flows for over thirty years. During the past fifteen years this same current meter principle has been applied as a primary element for the measurement of main-line flows by R. W. Sparling, of Los Angeles, and has proven itself well suited for this purpose.

The Propeller-Meter

The propeller-type meter, as illustrated in Figure I, is made up of a six-bladed propeller approximately eight-tenths of the pipe diameter mounted transversely in the center of the pipe. The propeller is made of a plastic material, having a specific gravity of approximately one, and is suitable for use in either cold water or hot water up to 300° F. The propeller practically displaces its own weight in water and is mounted on ball bearings which allow it to rotate freely in the stream of water.

Calibration

Experiments and experience have shown that a propeller will rotate in direct proportion to the velocity of water in a pipe at all flows above an approximate pipe velocity of one-half linear foot per second. The index, or the number of cubic feet passing through the pipe for each turn of the meter shaft, is determined from volumetric tests. From this index proper gears are furnished for direct totalization of the flow.

Characteristics

The current metering principle has certain characteristics that make it particularly well adapted for main-line measurement, as the action of the propeller is solely dependent upon the velocity of flow in the line. The pressure requirement is only such as to always maintain a full pipe of water. The loss of pressure caused by the metering element in sizes 6" and larger does not exceed six (6) inches of water at normal maximum pipe velocity.

Continued accuracy of the current type meter is dependent chiefly upon maintaining a clean metering section and a propeller free from incrustation. The plastic propeller has proven itself well suited for this purpose as it is practically inert and will resist both corrosion and electrolytic action. In order to maintain a uniform meter section the propeller assembly may be mounted in either a cast-iron or steel tube having a bronze liner.

Installation

The metering element may be installed directly on existing pipe lines by means of a saddle either bolted or welded directly on the main. In such installations it is important that the inside diameter of the pipe be accurately determined. In all installations the meterhead may be removed from the pipe line very quickly and easily and it is normally good practice in sizes 12" and smaller to make a yearly inspection and sizes 16" and larger, every five years.

In selecting the proper location for the metering element it should be kept in mind that a normal flow of water, free from either spiralling or jet action, is required for accurate results. The spiralling effect that may be caused in a flow of water passing through a series of elbows, can be largely corrected by installing straightening vanes in the line preceding the meter.

Various forms of such vanes are in use but a very simple and effective correction may be made by the installation of three vanes — each approximately one-third the pipe diameter and two and one-half pipe diameters long, set at 120 degrees to each other in the pipe. These vanes will not eliminate a disturbance caused by a partially open gate-valve, but are effective for double elbows or other standard fittings and with such vanes the meter element may be installed with but two pipe diameters of straight approach.

One pipe diameter downstream is normally sufficient for all installations. Unless approximately ten pipe diameters are available ahead of the meter, it is always good practice to use the straightening vanes. When the metering element is installed complete, with either a flange or bell and spigot tube, the three vanes mounted directly inside this metering section constitutes a complete unit ready for installation.

The metering element can be installed in either a vertical or horizontal pipe line and is suitable for mounting on either the suction or discharge side of a centrifugal pump.

Compound Design

Figure II is a sectional illustration of a compound meter suitable for use where an extremely wide range of flow measurement is required. A range of 150 to 1 is possible. A compound unit consists chiefly of two propeller-type meters working in series

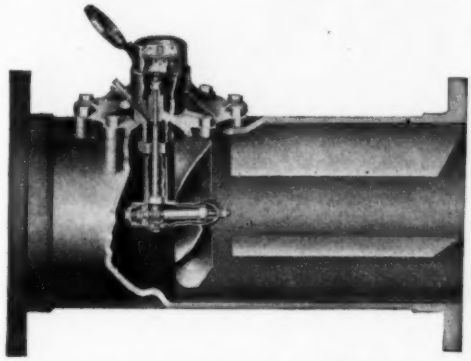


Fig. I—Cutaway View of Propeller Meter Note the flow straightening vanes in the tube, the whole unit ready for insertion as a single piece in the main-line.

through a pair of rachet clutches, allowing the meter revolving at the highest speed to drive the totalizing register. On the very low flows the large meter will under-register and thus allow the small meter to drive the totalizer. As the flows increase a pipe velocity is reached where the large meter has come into step and the small meter is operating at a high capacity. At this point the pressure loss caused by the small meter operating on the differential area of the compounding valve forces the valve to lift itself and allow the higher flow to by-pass the small meter.

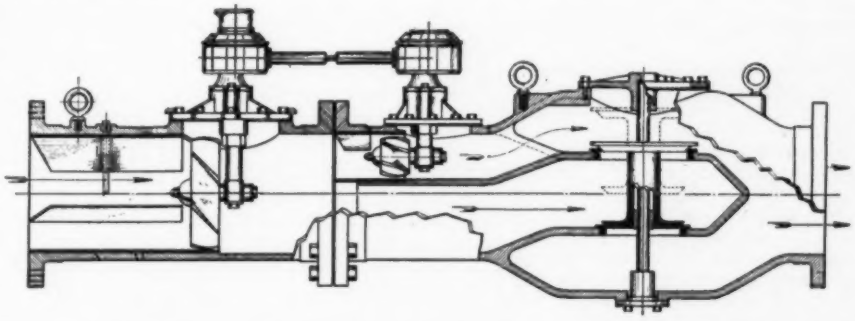


Fig. II—Section Through Propeller-Type Compound Meter Note valve which closes on low flows to cause entire flow to pass through small meter.

Although the minimum flow is considerably above that of the standard domestic compound meter it is well adapted for main-line measurement as the pressure loss caused by the entire unit does not normally exceed two pounds at maximum flow.

*President, J. M. Montgomery & Co., Engineer.

Indicating and Recording Elements

A rate-of-flow indicating and recording instrument may be used in conjunction with the straight totalizing primary element. The primary step of a current type meter is direct totalization. If the rate-of-flow indication is desired it must be obtained through a secondary step normally involving either a governor bowl or a friction plate revolving at a constant speed with a follower locating itself on the plate by impulses from the primary element.

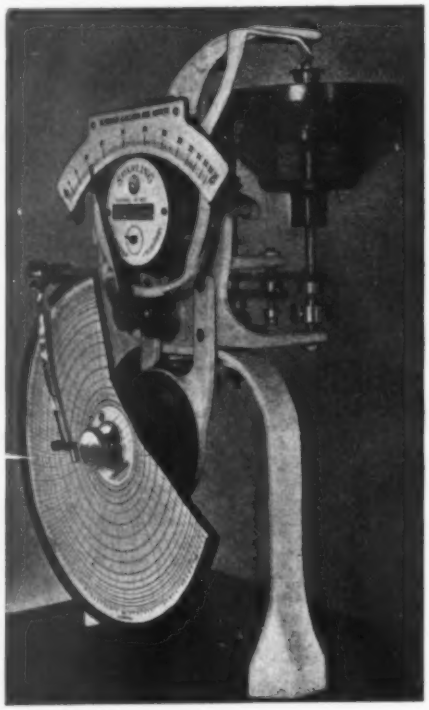


Fig. III—Typical Sparling Indicator-Recorder of the Mercury Governor Type.

Figure III illustrates the recording instrument involving a governor bowl which is driven either mechanically up to 15 feet from the metering element, or electrically to any distance required. The governor bowl consists chiefly of a float riding in the center of a mercury well. As the governor revolves, the mercury, through centrifugal force, finds its way through a small needle-valve to the outer chamber of the bowl, allowing the float in the center to have a rising and falling action in proportion to the revolving speed of the bowl. This type of governor is effective over approximately a 6-to-1 range and is extremely simple and well suited for normal pump like measurement.

A recording instrument utilizing the revolving friction plate, with a follower locating itself by impulses from the metering element, as mentioned above, produces a straight line of rate indication over approximately 25-to-1 range and is well suited for recording flows of main distribution or consumption lines.

Recorders can be adapted to show the combined flows of two or more pipe lines and combinations may be furnished showing the net total of several lines where the flow of any one pipe may be in either forward or reverse direction.

Application in Chemical Feed Control

Automatic control of chemical feeders by either mechanical or electrical means is readily obtainable from a current meter element as the shaft of the meter is revolving in direct proportion to the flow and considerable load may be applied without affecting the rotating speed of the propeller.

If given the periodic inspection required by any primary metering element, the characteristic of low pressure loss and accuracy over a wide range of flow allows the principle of the current meter to fill an important part in the waterworks field.

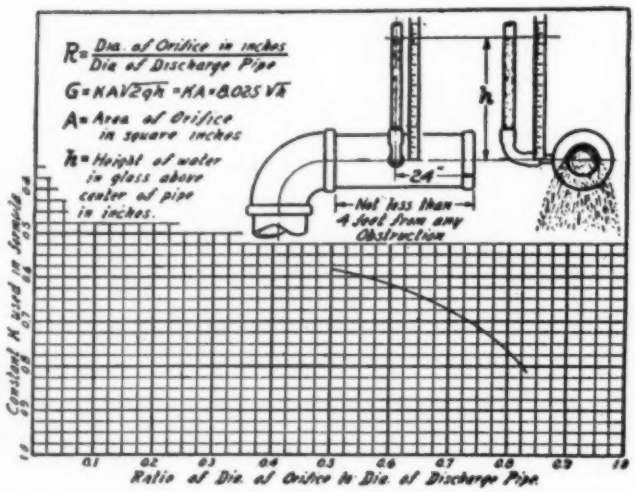
The propeller-type meter is not suitable for measuring raw sewage and is not generally recommended for measurement of a sewage effluent unless it has passed through a filter bed. Care must also be taken when installing such meters on raw water gravity lines that screens are provided at the inlet structure to prevent excessive algae or weeds from passing down the pipe and stalling the meter propeller.

MEASURING FLOWS BY THE ORIFICE METHOD

The orifice method is a simple way to measure flow of water from a pipe discharging horizontally into the open air. The sketch shows the general arrangement.

A plate or cap is affixed to the end of the pipe with the circular orifice in the exact center of the pipe. The size of orifice should be from one-half to three-quarters of the size of the pipe, but must be of such size that it will run full of water.

A hole for ⅛-in. pipe should be drilled and tapped 24 in. back from the orifice and a short ⅛-in. nipple screwed in until the inner end is exactly flush with the inner wall of the pipe. One end of a piece of rubber hose is slipped over the end of the nipple and the other end over a glass tube, which should be supported in a vertical position.


R = Dia. of Orifice in inches / Dia. of Discharge Pipe
G = KAV2gh = KA = 8.025 √h
A = Area of Orifice in square inches
h = Height of water in glass above center of pipe in inches.
24"
Not less than 4 feet from any Obstruction
Constant K used in formula
Ratio of Dia. of Orifice to Dia. of Discharge Pipe

Ratio R is the diameter of the orifice divided by the inside diameter of the pipe, and the proper value of K is found from the curve. In the formula A is figured as the area of the orifice in square inches, G = 32.2, and H is read as the height in inches of the water in the glass tube above the center of the pipe. Gallons per minute (g) then can be figured.

For convenience when determining capacities during pumping tests, the accompanying table for various orifices commonly employed will prove useful.

ORIFICE TABLE FOR DETERMINING WATER FLOW

ORIFICE TABLE FOR DETERMINING WATER FLOW

Compiled by the Engineering Department of Layne and Bowler, Inc., from original calibrations made in Hydraulic Laboratories at Purdue University.

Head in Inches	3" Orifice		4" Orifice		5" Orifice		6" Orifice		7" Orifice	8" Orifice	Head in Inches
	4 in. Pipe	6 in. Pipe	6 in. Pipe	8 in. Pipe	6 in. Pipe	8 in. Pipe	8 in. Pipe	10 in. Pipe	10 in. Pipe	10 in. Pipe	
5	100	76	145	140	280	220	380	320			5
5.5	104	79	153	145	293	230	394	333			5.5
6	108	82	160	150	305	240	408	345			6
6.5	111	85	167	155	316	250	421	358			6.5
7	115	88	172	160	328	260	433	370			7
7.5	119	91	179	165	339	270	446	383			7.5
8	122	94	185	170	350	280	458	395	600	935	8
8.5	125	96	190	175	361	289	471	408	617	963	8.5
9	128	99	195	180	372	298	483	420	633	992	9
9.5	130	102	200	185	383	307	495	433	650	1016	9.5
10	133	104	205	190	393	316	508	445	666	1040	10
10.5	137	107	210	195	402	324	521	458	682	1060	10.5
11	140	109	215	200	412	330	533	470	698	1080	11
11.5	143	111	220	204	421	338	545	480	713	1100	11.5
12	146	114	225	208	430	346	556	490	728	1120	12
12.5	149	116	230	212	439	354	567	500	743	1139	12.5
13	151	118	234	216	448	362	578	510	757	1158	13
13.5	154	121	239	219	457	369	589	520	771	1176	13.5
14	157	123	243	224	465	376	599	530	785	1194	14
14.5	159	126	247	227	473	383	609	540	799	1212	14.5
15	162	128	250	231	480	390	618	550	812	1230	15
15.5	164	130	254	234	488	396	627	559	825	1248	15.5
16	167	132	257	238	495	402	636	568	838	1266	16
16.5	170	134	261	241	503	408	645	577	851	1284	16.5
17	172	136	264	245	510	414	654	586	863	1302	17
17.5	175	138	268	249	517	420	663	595	875	1319	17.5
18	178	140	271	252	524	426	672	604	887	1336	18
18.5	180	142	275	256	530	432	681	612	899	1353	18.5
19	183	144	278	259	536	438	690	620	910	1370	19
19.5	185	146	282	263	542	444	699	628	922	1387	19.5
20	187	148	285	266	548	449	708	636	933	1404	20
20.5	190	150	289	270	554	455	717	643	945	1421	20.5
21	192	152	292	273	560	460	726	650	956	1438	21
21.5	195	154	295	275	566	465	735	657	968	1455	21.5
22	197	156	299	279	572	470	744	664	979	1471	22
22.5	199	158	302	282	578	475	752	671	990	1486	22.5
23	201	160	305	285	584	479	760	678	1001	1500	23
23.5	203	162	307	288	590	484	768	685	1012	1515	23.5
24	205	164	310	291	596	488	776	692	1022	1529	24
24.5	207	165	314	294	602	492	784	699	1033	1543	24.5
25	210	167	317	297	608	496	791	706	1043	1557	25
25.5	212	169	320	300	614	500	798	713	1059	1571	25.5
26	214	171	323	303	620	504	805	720	1064	1585	26
26.5	216	173	326	305	626	508	812	727	1074	1599	26.5
27	219	174	329	308	632	512	818	734	1084	1613	27
27.5	221	176	332	311	638	516	825	741	1094	1627	27.5
28	222	177	335	314	644	520	831	747	1104	1641	28
28.5	224	179	337	317	650	524	838	754	1114	1655	28.5
29	226	180	340	320	656	528	844	760	1124	1669	29
29.5	228	182	343	323	662	532	851	767	1134	1683	29.5
30	230	183	346	325	668	536	857	773	1143	1697	30
30.5	232	185	348	328	674	540	863	780	1153	1711	30.5
31	235	186	351	330	680	544	869	786	1162	1725	31
31.5	236	188	354	333	686	548	876	793	1172	1739	31.5
32	239	189	357	335	692	552	882	799	1181	1753	32
32.5	240	191	360	338	697	556	889	806	1191	1767	32.5
33	242	192	363	340	703	560	895	812	1200	1791	33
33.5	244	194	366	342	709	564	901	818	1209	1795	33.5
34	246	195	369	345	715	568	907	824	1218	1809	34
34.5	248	196	372	247	720	572	913	830	1227	1823	34.5
35	250	197	375	349	726	576	919	836	1235	1837	35
35.5	252	198	377	351	732	580	925	842	1243	1851	35.5
36	254	200	380	354	737	584	931	847	1251	1865	36

Head in Inches	3" Orifice		4" Orifice		5" Orifice		6" Orifice		7" Orifice	Head in Inches
	4 in. Pipe	6 in. Pipe	6 in. Pipe	8 in. Pipe	6 in. Pipe	8 in. Pipe	8 in. Pipe	10 in. Pipe	10 in. Pipe	
36.5	256	201	383	356	743	588	937	852	1259	36.5
37	257	203	385	358	748	592	943	857	1266	37
37.5	259	204	388	360	754	596	949	862	1274	37.5
38	260	205	390	363	759	600	955	867	1281	38
38.5	262	206	393	365	765	604	961	872	1289	38.5
39	263	208	396	367	770	608	967	877	1295	39
39.5	265	209	398	369	776	612	974	882	1304	39.5
40	266	210	401	371	781	616	979	887	1311	40
40.5	267	211	403	373	786	620	985	891	1319	40.5
41	269	212	406	375	790	624	990	896	1326	41
41.5	271	213	408	378	795	628	996	901	1334	41.5
42	272	214	411	380	800	631	1001	906	1341	42
42.5	274	216	413	382	805	635	1007	910	1349	42.5
43	275	217	415	384	810	638	1012	915	1356	43
43.5	277	218	418	386	815	642	1018	920	1364	43.5
44	278	219	420	388	820	645	1023	925	1371	44
44.5	280	220	422	390	824	649	1029	929	1379	44.5
45	281	222	425	392	828	652	1034	934	1387	45
45.5	283	223	427	394	832	656	1040	939	1394	45.5
46	284	224	429	396	837	659	1045	944	1401	46
46.5	285	225	432	399	842	663	1051	948	1409	46.5
47	287	227	434	401	847	666	1056	953	1416	47
47.5	289	228	437	403	851	669	1062	958	1424	47.5
48	290	229	440	405	855	672	1067	963	1431	48
48.5	292	230	442	407	859	676	1073	967	1439	48.5
49	293	231	444	409	863	679	1078	972	1446	49
49.5	294	232	446	411	868	683	1084	977	1454	49.5
50	296	234	448	413	872	686	1089	982	1461	50
50.5	298	235	450	415	876	690	1095	986	1469	50.5
51	300	236	453	417	880	693	1100	991	1476	51
51.5	301	237	455	419	884	697	1105	996	1484	51.5
52	302	238	457	421	888	700	1110	1000	1491	52
52.5	303	239	459	423	892	704	1115	1005	1499	52.5
53	304	240	461	425	896	707	1120	1009	1506	53
53.5	305	241	463	427	900	711	1125	1014	1513	53.5
54	307	243	465	429	904	714	1130	1018	1520	54
54.5	309	244	467	431	908	718	1135	1023	1527	54.5
55	310	246	469	433	912	721	1140	1027	1534	55
55.5	311	247	471	435	915	725	1145	1032	1541	55.5
56	313	248	472	437	919	727	1150	1036	1548	56
56.5	314	249	474	439	923	730	1155	1040	1554	56.5
57	315	250	476	441	927	733	1160	1044	1560	57
57.5	316	251	478	443	930	736	1165	1046	1567	57.5
58	317	252	480	445	934	739	1170	1052	1574	58
58.5	319	253	482	447	938	742	1175	1056	1580	58.5
59	320	254	485	449	942	745	1180	1060	1586	59
59.5	321	256	487	451	945	748	1185	1064	1592	59.5
60	323	257	489	453	948	751	1190	1068	1598	60
60.5	324	258	491	455	951	754	1195	1072		60.5
61	325	259	492	457	955	757	1200	1076		61
61.5	326	261	494	459	958	760	1205	1080		61.5
62	328	262	496	461	961	763	1209	1084		62
62.5	329	263	498	463	964	766	1214	1088		62.5
63	330	264	500	465	968	769	1218	1092		63
63.5	331	265	502	467	971	772	1223	1096		63.5
64	333	266	504	469	974	775	1227	1099		64
64.5	334	267	507	471	977	778	1232	1103		64.5
65	335	268	509	472	981	781	1236	1106		65
65.5	336	269	511	474	984	784	1241	1110		65.5
66	338	271	513	475	988	787	1245	1113		66
67	340	273	517	479	995	793	1254	1120		67
68	343	275	520	483	1002	799	1263	1127		68
69	346	277	523	487	1009	805	1272	1134		69
70	349	280	525	491	1016	811	1280	1140		70

AUTOMATIC OPERATION OF CENTRIFUGAL PUMPS

A Discussion of Fundamentals of Automatic Control

By W. D. HAENTJENS
Engineer, Barrett, Haentjens & Co., Hazelton, Pa.

THE purpose of automatic pumping is, in most cases, the achievement of more economical operation through the elimination of an attendant. At times, the purpose is greater safety of operation.

In the simplest case of automatic pump control, that is, pumps operating with a positive head on the suction, no special equipment except float switches and automatic starters is required.

Pumps operating with a suction lift can be equipped with a footvalve which keeps the pump filled with water between runs. Automatic control here can be the same as that for pumps operating with a head on the suction. However, the use of a footvalve results in somewhat unreliable control. There are several objections to the use of a footvalve; (1) the pump is unprotected from water-hammer and failure of the pump casing may result; (2) the footvalve may leak, thus leaving the pump without water. When the pump is started, damage would undoubtedly result to the pump; (3) friction in the footvalve results in an increased suction lift.

Components of Automatic Control Systems

A brief description of the operation of a few of the components of an automatic control system (Fig. 1) is perhaps in order here.

I. Check Valve with Switch—The check value is always placed on the discharge end of the pump. To the flap of this valve is attached a switch. This switch may be one such as a lever-operated contact switch or a Mercoid switch. The switch, normally open, closes when the pump goes into operation and remains closed as long as the pump is discharging water.

II. Priming Valve—This is an automatic valve which is mounted on the top of the centrifugal pump casing. It permits the passage of air through it during the priming operation, but closes when water at the operating pump pressure attempts to flow through it. It remains closed only so long as the pump is in operation.

III. Vacuum Breaker with Priming Switch—This unit is mounted so as to be higher than the priming valve. Air exhausted by the priming pump passes through the pump casing, then through the priming valve and vacuum breaker to the priming pump. The action of the vacuum breaker is: (1) to prevent water from entering the priming pump, (2) to actuate the priming switch when priming is completed, (3) to automatically drain and prepare for a new priming cycle once the pump is in operation. The priming switch is normally open. When the water enters the vacuum breaker chamber, the float rises and simultaneously closes the switch and opens an air valve. Air, entering through this valve, breaks the vacuum and permits the water to drain out of the chamber.

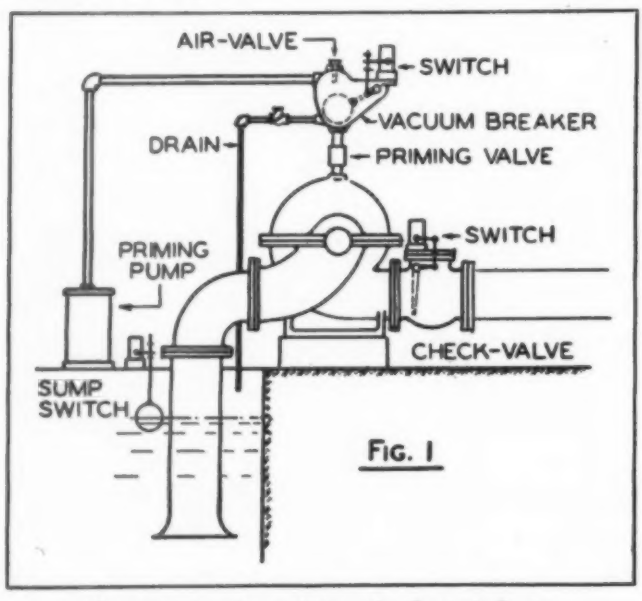


FIG. 1

Components of an Automatic Control System

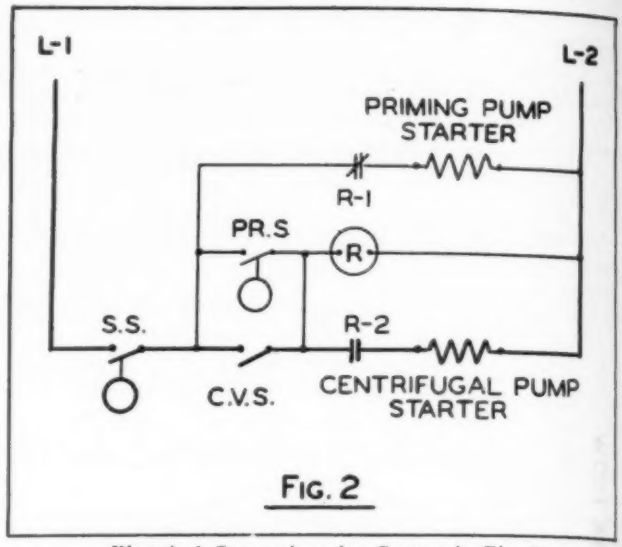


FIG. 2

Electrical Connections for System in Fig. 1

For safe and dependable control of pumps operating with a suction lift, a vacuum pump is used. Reduced pressure produced by the vacuum pump permits the water to rise from the sump into the pump, filling the pump casing and float chamber. As the float in the chamber rises, it operates the priming switch which is connected with the starting circuit of the centrifugal pump motor. Shutting down of the priming pump is also accomplished at the same instant.

In its simplest form these arrangements are shown diagrammatically in Figure 1. The check valve prevents the entrance of air during the priming period and arrests the back flow of water when the discharge line is filled and the pump stands idle. In the latter condition, the pump in starting must produce a pressure sufficiently great to open the main-line check valve against the full water column pressure. This fact makes priming difficult when there are air pockets in the suction line. The air from these pockets, when drawn into the pump, gathers around the impeller hub, causing the pump to lose suction and preventing it from building up sufficient pressure to start the flow of water through the check valve.

In order to remove this air, the pump must be stopped and allowed to remain idle sufficiently long for all the entrapped air to rise to the top of the pump casing. It can then be removed by the priming pump at the next priming attempt.

It is therefore evident that automatic control must provide for more than one start and for a delay between starts. Not only air pockets, but also air leaking through the stuffing boxes may destroy the prime. At the first start, water is forced into the water seal ring of the stuffing box. This stops or so greatly reduces the leakage that the pump will be properly primed after two or perhaps three priming attempts.

Should the seal water not stop the leakage, there may result a continuous starting and stopping of the priming pump and the centrifugal pump. Automatic control must therefore limit the number of starts to three or four. The justification for this feature was clearly illustrated by experience in early automatic installations. In one instance, one standard automatic starter for a squirrel cage motor made 450 starts from 1 p. m. Monday afternoon to 7 a. m. Tuesday morning, a total of 25 starts per hour for 18 hours. This starter was roasted.

The air leak may be so large that the priming pump cannot dispose of all the air leaking into the system and therefore cannot draw the water into the float-chamber. In that case, the priming pump will continue to run indefinitely. Thus in order to prevent damage to the priming pump or over-flowing of the sump, automatic control should limit the time required for priming.

Referring again to Figure 1, the priming valve is held open by the action of a spring and closed by water pressure when the pump begins to discharge water. As soon as this valve closes, the float-chamber begins to drain and its switch will open. It is

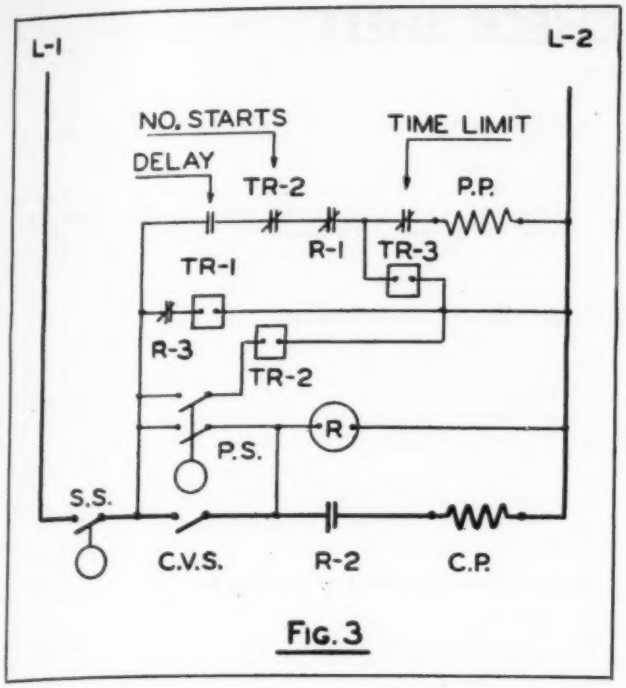


FIG. 3

The Time Relay Circuit for Preventing False Pump Starts

important that the float-chamber drain slowly so that sufficient time is permitted for the pump to build up speed and close the check valve switch before the priming switch opens. If this did not happen, the pump would immediately stop.

Electrical Circuits

Figure 2 shows the electrical connections for the above arrangement. When the water rises in the sump, closing the sump switch, current flows from Line 1, through the sump switch, SS, and the normally closed contact, R-1 of the relay R, thus energizing the priming pump starter. The priming pump begins operation. When priming is completed and the water rises into the priming chamber, the priming switch closes, energizing the relay R. This opens contact R-1, stopping the priming pump, and closes R-2, energizing the centrifugal pump starter. As the pump builds up speed and begins to discharge water, the check valve switch will shunt out the priming switch. The priming switch opens as the priming chamber drains. The importance of slow draining of the chamber can be readily understood here. The pump is now operating under protection on the check valve switch. Should the pump lose the water, the check valve switch will open, and the pump will stop. Relay R is no longer energized and R-2 drops out and R-1 closes again. If the sump switch is still closed, the priming cycle will be repeated.

Prevention of False Starts

To prevent too many false starts, a time relay is placed in the circuit, controlled by the vacuum breaker switch. The simplified wiring diagram, with other features, is shown in Figure 3. The timing action of this relay, TR-2 occurs only while the priming switch is closed. When a sufficient time for several priming attempts has elapsed, TR-2 opens.

The complete automatic action is exemplified by Figure 3. This action is as follows: When the water in the sump rises and closes the sump switch, SS, current flows from Line 1 through normally closed contact R-3 and time delay relay, TR-1, to Line 2. Then, TR-1 begins to time. After it has timed out, contact TR-1 closes and now permits current to flow through the normally closed contact TR-2 of time relay TR-2, then through the normally closed contact R-1 and through the normally closed contact TR-3 of time relay HR-3, to the priming pump starter which is now energized and starts the priming pump. When priming is completed and the priming chamber is filled, the priming switch PS closes and time relay TR-2 begins to time. At the same instant, relay R is energized, closing R-2 and opening R-3 and R-1, thus the centrifugal pump starter is energized and the pump starts; the priming pump stops and time relay TR-1 is reset.

Time relay TR-2 is cumulative, i.e., TR-2 opens only when the total time required for several normal starts is exceeded. Time limit relay, TR-3, is set for about 15 to 30 minutes to limit the time of operation of the priming pump during any one prime. Time delay relay, TR-1, has been reset by the opening of R-3 so that it will be able to delay a second priming attempt if the first was unsuccessful. Since large pumps are idle for as long as 30 seconds, TR-1 is set to trip in about one minute. If the pump is still not in operation after several priming attempts, time relay TR-2 locks out so that the system now completely ceases operation, but an alarm signal sounds either in the foreman's office or at any desired location. The system will not operate again until the trouble has been remedied and time relay, TR-2, reset by hand. Note, however, that all relays must automatically reset when the sump switch opens.

It is not the intention of this article to give a detailed description of the mechanical and electrical devices. These may vary considerably but they should provide the sequence of operation and protection outlined. Additional features such as pressure and vacuum regulator switches, water level indicators, thermostats on the pump main and thrust bearings, etc., may be added for greater safety. The most recent innovation is the use of electrodes in the sump in place of float switches.

PRESSURE IN POUNDS PER SQUARE INCH FOR DIFFERENT HEADS OF WATER

Head In Feet	0	1	2	3	4	5	6	7	8	9
0	....	.43	.87	1.30	1.73	2.16	2.60	3.03	3.46	3.90
10	4.33	4.76	5.20	5.63	6.06	6.50	6.93	7.36	7.79	8.23
20	8.66	9.09	9.53	9.96	10.39	10.83	11.26	11.69	12.12	12.56
30	12.99	13.42	13.86	14.29	14.72	15.16	15.59	16.02	16.45	16.89
40	17.32	17.75	18.19	18.62	19.05	19.49	19.92	20.35	20.78	21.22
50	21.65	22.08	22.52	22.95	23.38	23.82	24.25	24.68	25.11	25.55
60	25.98	26.41	26.85	27.28	27.71	28.15	28.58	29.01	29.44	29.88
70	30.31	30.74	31.18	31.61	32.04	32.48	32.91	33.34	33.77	34.21
80	34.64	35.07	35.51	35.94	36.37	36.81	37.24	37.67	38.10	38.54
90	38.97	39.40	39.84	40.27	40.70	41.14	41.57	42.00	42.44	42.87
100	43.30	43.74	44.17	44.60	45.03	45.47	45.90	46.33	46.77	47.20
110	47.63	48.07	48.50	48.93	49.36	49.80	50.23	50.66	51.10	51.53
120	51.96	52.40	52.83	53.26	53.69	54.13	54.56	54.99	55.43	55.86
130	56.29	56.73	57.16	57.59	58.02	58.46	58.89	59.32	59.76	60.20
140	60.62	61.06	61.49	61.92	62.35	62.79	63.22	63.65	64.09	64.52
150	64.95	65.39	65.82	66.25	66.69	67.12	67.55	67.98	68.42	68.85
160	69.28	69.72	70.15	70.58	71.02	71.45	71.88	72.31	72.75	73.18
170	73.61	74.05	74.48	74.91	75.35	75.78	76.21	76.64	77.08	77.51
180	77.94	78.38	78.81	79.24	79.68	80.11	80.54	80.97	81.41	81.84
190	82.27	82.71	83.14	83.57	84.01	84.43	84.87	85.30	85.74	86.17
200	86.60	87.04	87.47	87.90	88.33	88.77	89.20	89.63	90.07	90.50

PUMP TROUBLE CHECK SHEET

(Courtesy, Goulds Pumps, Inc.)

WHEN investigating trouble with Goulds Pumps, always remember that every pump has been tested at the factory and is mechanically correct when shipped. Discounting the possibility of damage during shipment, most of the trouble in the field is due to faulty installation. Check the following points:

Centrifugal Pumps

Investigation shows that the majority of troubles with CENTRIFUGAL PUMPS result from faulty conditions on the suction side. Except for mechanical trouble, nine times out of ten, this is where to look for the cause.

1. No water delivered

(a) Priming—Casing and Suction Pipe not completely filled with liquid
x (b) Speed too low
(c) Discharge head too high—check vertical head (particularly friction loss)
(d) Suction Lift too high (suction pipe may be too small or long causing excessive friction loss). Handling cold water, total lift including friction loss in suction pipe should not exceed 15 feet, or in any case be more than 2/3 total head. Check with gauge.
(e) Impeller or suction pipe or opening completely plugged up
(f) Wrong direction of rotation
(g) Air pocket in suction line
(h) Stuffing Box Packing worn—or water seal plugged—allowing leakage of air into pump casing
(i) Air leak in suction line
(j) Not enough suction head for hot water or volatile liquids. Check carefully as this is a frequent cause of trouble on such service

2. Not enough water delivered

(a) Priming—Casing and Suction Pipe not completely filled with liquid
x (b) Speed too low
(c) Discharge head higher than anticipated—check, particularly friction loss
(d) Suction Lift too high (suction pipe may be too small or long causing excessive friction loss). Handling cold water, total lift including friction loss in suction pipe should not exceed 15 feet nor in any case be more than 2/3 total head. Check with gauge
(e) Impeller or suction pipe or opening partially plugged up
(f) Wrong direction of rotation
(g) Air pocket in suction line
(h) Stuffing Box Packing worn—or water seal plugged—allowing leakage of air into pump casing
(i) Air leak in suction line
(j) Not enough suction head for hot water or volatile liquids. Check carefully as this is a frequent cause of trouble on such service
(k) Foot Valve too small
(l) Foot Valve not immersed deep enough
(m) Mechanical defects:
Wearing rings worn
Impeller damaged
Casing packing defective

3. Not enough pressure

x (a) Speed too low
(b) Air in water
(c) Measure Impeller diameter
(d) Mechanical defects:
Wearing rings worn
Impeller damaged
Casing packing defective
(e) Wrong direction of rotation
(f) Be sure pressure gauge is in correct place. Not on top of casing

4. Pump works for a while and then quits

(a) Leaky suction line
(b) Stuffing Box Packing worn—or water seal plugged—allowing leakage of air into pump casing
(c) Air pocket in suction line
(d) Not enough suction head for hot water or volatile liquids. Check carefully as this is a frequent cause of trouble on such service
(e) Air or gases in liquid
(f) Suction Lift too high (suction pipe may be too small or long causing excessive friction loss). Handling cold water, total lift including friction loss in suction pipe should not exceed 15 ft. nor in any case be more than 2/3 total head. Check with gauge

5. Pump takes too much power

(a) Speed too high
(b) Head lower than rating: pumps too much water
(c) Liquid heavier than water. Check viscosity and specific gravity
(d) Mechanical defects:
Shaft bent
Rotating Element binds
Stuffing Boxes too tight
Pump and Driving Unit misaligned
(e) Wrong direction of rotation

6. Pump leaks excessively at stuffing box

(a) Packing is worn or not properly lubricated
(b) Packing is incorrectly inserted or not properly run in
(c) Packing is not right kind for liquid handled
(d) Shaft scored

7. Pump is noisy

(a) Hydraulic noise-cavitation, suction lift too high. Check with gauge
(b) Mechanical defects:
Shaft bent
Rotating parts bind, are loose or broken
Bearings worn out
Pump and driving unit misaligned

x When connected to electric motors, check up whether motor is across the line, wiring correct, and receives full voltage. When connected to steam turbines, make sure that turbine receives full steam pressure.

Vertical Centrifugal Sump Pumps

In general, the same remarks as given for "Centrifugal Pumps" apply to these units. By the very nature of the service on which they are commonly used, lack of capacity or pressure can be caused by clogging due to the solid matter in suspension in the liquid handled.

This, in addition to the other general remarks should always be checked and if clogging occurs, adequate screening of pump suction should be provided.

Lack of capacity or pressure may be because total head was incorrectly figured. Total head of a sump pump is vertical elevation from water level in sump (not pit cover) plus friction loss in piping from pump nozzle to point of discharge.

Triplex Pumps

1. No water delivered

(a) Priming—(Fill Valve Boxes and Pump Cylinders with water)
(b) Suction Line completely plugged up
(c) Suction Lift too high (over 22 ft.) Check with gauges
(d) Not enough positive suction head for hot water volatile or thick liquids

2. Not enough water delivered

(a) Priming—Fill Valve Boxes and Pump Cylinders with water
x (b) Speed too low
(c) Foreign matter under valves
(d) Suction line partially plugged up
(e) Suction Lift too high (over 22 ft.) Check with gauges
(f) Not enough suction head for hot water, volatile or thick liquids
(g) Mechanical defects:
Valves worn or warped and do not seat properly
Plunger Packing worn
Plungers worn

3. Not enough pressure

(a) Air in water
(b) Foreign matter under valves
(c) Mechanical defects:
Valves worn or warped and do not seat properly
Plunger Packing worn
Plungers worn

4. Pump pounds

(a) Air in water
(b) Suction Lift too high (over 22 ft.) Check with gauges
(c) Surges in suction line (especially on booster pumps)
(d) Not sufficient suction head for hot water, volatile or thick liquids
(e) Excessive speed
(f) Speed too high for thick, viscous or hot liquids, so that pump barrel cannot fill
(g) Pressure greater than catalog rating of pump. Excessive strain on moving parts and frame
(h) Mechanical defects:
Loose main bearings
Loose crossheads
Loose crosshead pins
Loose crank pins

5. Pump takes too much power

(a) Speed too high
(b) Higher pressure than catalog rating of pump
(c) Liquid heavier than originally specified. Check viscosity and specific gravity
(d) Plungers packed too tight
(e) Mechanical defects:
Poor fitting of moving parts
Bearings too tight
Gears not properly assembled
x See note under Centrifugal Pumps

Rotary Pumps

1. No water delivered

(a) Priming—See that Casing and Suction Pipe are filled with liquid
(b) Suction Line completely clogged
(c) Suction Lift too high (Suction pipe may be too small or long causing excessive friction loss.) Check with gauges
(d) Wrong direction of rotation
(e) Not enough positive suction head for hot water, volatile or thick liquids

2. Not enough water delivered

(a) Priming
x (b) Speed too low
(c) Suction Line partially clogged
(d) Suction Lift too high (Suction pipe may be too small or long, causing excessive friction loss.) Check with gauges
(e) Not enough positive suction head for hot water, volatile or thick liquids
(f) Liquid too thick or viscous. Check viscosity

3. Not enough pressure

(a) Air in water or liquid
(b) Mechanical defects:
Cams, Gears or other working parts worn—too much clearance
Stuffing Box Packing worn

4. Pump makes too much noise

(It must be borne in mind that some noise is always natural in a rotary pump)
(a) Air in water or liquid handled
(b) Speed too high—especially when handling thick or volatile liquids
(c) Too much suction lift—pump not filling with liquid
(d) Mechanical defects:
Cams, Gears, or other working parts worn, loose or broken

5. Pump takes too much power

(a) Speed too high
(b) Discharge pressure higher than originally specified
(c) Liquid heavier than originally specified. Check specific gravity and viscosity
(d) Stuffing Box Packing too tight
(e) Mechanical defects.
Poor fit of working parts—binding at some point
Bearings too tight
Misalignment between pump and driver
x See note under Centrifugal Pumps

Centrifugal Pumps

Total suction lift must never exceed suction lift limits of pump. The remarks in the trouble check lists apply to Centrifugal Pumps in general. It must be borne in mind that when dealing with very small Centrifugal Units, 1" size and less, suction lift is further limited, and in some cases a positive head is absolutely necessary to secure proper operation. The recommendations in our catalog for these 1" and smaller pumps should be followed.

Use pipe of ample size—at least the same diameter as suction of pump. Suction pipe should have sufficient submergence to prevent air from being indrawn. Suction pipe should be air tight and slope gradually up towards pump to prevent air pockets (as shown below). If suction pipe is larger diameter than suction opening of pump, an eccentric reducer should be used to prevent high spot in line and formation of air pocket.

Check Valve in discharge line close to pump to prevent draining back thru pump.

Gate Valve next to Check Valve, on far side of pump, to close off line for pump or check valve repairs and to control capacity of pump.

An air tight suction pipe and properly sealed stuffing box especially important with Centrifugal Pumps which are not positive in action.

Stuffing Box is sealed usually by water under pressure from casing volute. This seal pipe and lantern ring in stuffing box should be clean and offer free flow to liquid—otherwise air drawn into pump and satisfactory operation destroyed.

Reciprocating and Rotary Pumps

For safety a relief valve set to open slightly above maximum pump pressure should be installed in discharge line near pump.

EVALUATION OF PUMP BIDS BY A SIMPLE METHOD AND DETERMINATION OF POWER COSTS

The estimated cost of electrical energy for pumping liquids over any assumed period of time, which is to be added to the bid price for pumping equipment for determination of its evaluated cost, may be obtained through the use of the formula

$$C = \frac{3.14\ Qhc}{E}$$

Where C = Estimated power cost in dollars over the assumed evaluation period.
Q = Estimated number of *millions* of gallons to be pumped during the same period.
h = Head in feet, on which guaranteed efficiency is based.
c = Cost, in dollars, per KWH of electrical energy.
E = Guaranteed overall pump and motor (input-output) efficiency at head "h," expressed as decimal fraction and not as a percentage.

The constant "3.14" is suitable for slide rule calculations and is sufficiently accurate for most cases, as the assumptions made are too broad for accurate estimates. Should it be necessary to determine the cost to the dollar (in case of very close bids and the selection must be made on a price basis), the figure 3.13975 should be used.

Example: Assume
Q = 2,000 million gallons
h = 100 feet
c = $0.01 per KWH
E = 0.7 (70 per cent)

$$C = \frac{3.14 \times 2{,}000 \times 100 \times 0.01}{0.7}$$

$$= \$8{,}970.$$

This simplified formula for evaluating pump bids was developed by C. I. Dodd of Black & Veatch, Engrs., Kansas City, Mo

ANDERSON VALVE CORPORATION

Oliver Building
PITTSBURGH, PA.

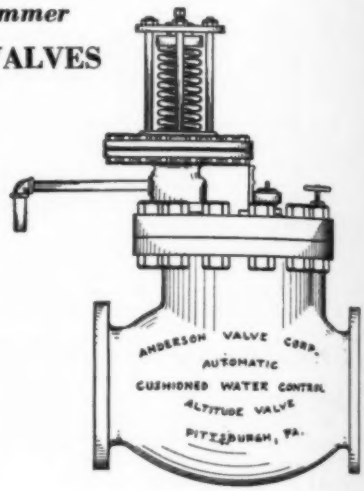
Anderson Automatic Valves for Water Control

Anderson Cushioned Valves Prevent Water Hammer

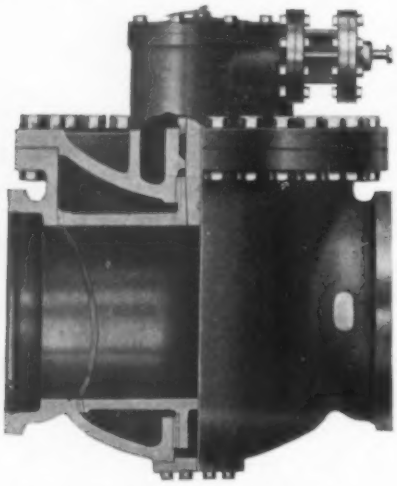
AUTOMATIC CUSHIONED ALTITUDE VALVES

Service: For automatic fluid level control in tanks, standpipes, reservoirs or other containers where separate inlet and outlet pipes are used. Valve shown at the left exhausts to atmosphere. Valve illustrated at right is adapted for installations where ordinary exhaust to atmosphere is not permitted.

Cushioned: In the opening operation by water and in the closing operation by air. Prevents water hammer, shock or jar on high or surging pressures.

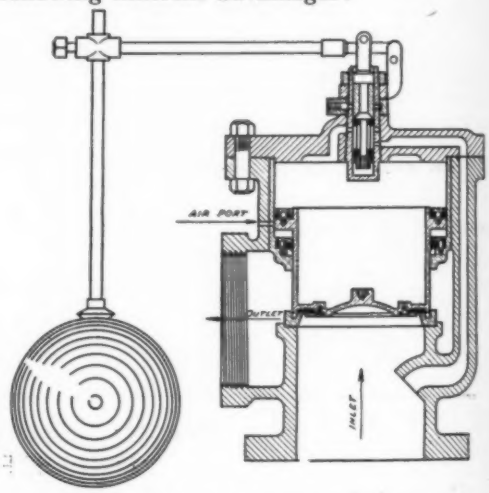


MANUAL OR HYDRAULIC CONE VALVES



Anderson Manual or Hydraulic Cone Valves offer the usual cone valve advantages such as: drop tight in either open or closed positions, reduction of water hammer, negligible loss of head, installation requiring small head room, minimum operating time, seat protection in either position, seat cleaning action, flexible unit construction, sturdy construction with large factor of safety in material and also provide the following inherent advantages:

1. Superior Mechanical Leverage Advantage
2. Automatic Adjustment for Wear
3. Simplified Design
4. Balanced Plug Construction



AUTOMATIC PRESSURE REDUCING VALVES

Service: For maintaining a constant delivery pressure in distributing mains regardless of change in volume requirements. For high or low pressure.

Cushioned: In the opening operation by water and in the closing operation by air. Prevents water hammer.

Valves may be furnished with various controls to meet individual conditions.

AUTOMATIC CUSHIONED WATER FLOAT VALVES

Service: For automatically maintaining any uniform water level in tank, standpipe, reservoir or other containers. For high or low pressure.

Cushioned: In the opening operation by water and in the closing operation by air. Smooth operation prevents water hammer or other shock. Copper float; valve fully bronze mounted throughout.

WATER HAMMER

Its Study and Correction

By HENRY RYON

Late Senior Sanitary Engineer
New York State Department of Public Works, Albany, N. Y.

IN ORDER to provide water for Clinton Prison at Dannemora, N. Y., it was found necessary to use Chazy Lake as a source of supply and to lift the water over Dannemora mountain to the prison reservoir. This required the installation of a pumping station and a force main about 4½ miles long with a rise of 530 feet. The pumping station and pipe line were put in operation late in 1932, and almost immediately trouble was experienced due to the failure of the lead joints in the pressure line. The cause of these failures was apparently the high pressures developed when the pumps were stopped, and studies were made to determine the best method of reducing these high pressures.

Installation

The pumping equipment consists of two electrically driven four-stage centrifugal pumps each having a capacity of 390 gallons per minute against a head of 619 feet. The pumps are set approximately at normal lake level. The suction line is of 10-inch cast iron pipe and is about 400 feet long. The discharge main is of 8-inch cast iron bell and spigot pipe, Class G to Class B, and is 23,720 feet long. The static head at the pumps is 530 feet, the equivalent of approximately 230 pounds per square inch. There is a standard swing check valve on the suction line and a similar check on the discharge line of each pump. A 6-inch spring loaded relief valve and an air chamber 8 inches by 96 inches in size were provided on the main discharge line near the pumps.

Line Pressure

In order to study the pressures in the discharge line a recording pressure gauge with a fast moving chart was connected to the line just beyond the relief valve. A typical pressure curve plotted by this gauge with one pump in operation and the relief valve and air chamber shut off is shown in Fig. 1.

The static pressure is 230 pounds per square inch. When one pump is started the pressure gradually rises to 310 pounds per square inch, the rise for each of the four steps of the starter showing distinctly, and then drops to the running pressure of 275 pounds per square inch. When the pump is stopped the pressure drops very quickly from 275 pounds per square inch to 90 pounds per square inch and then rises to 370 pounds per square inch. These subnormal and supernormal pressures continue at regular intervals, the variations above and below the static pressure becoming less and less as line friction gradually damps them out. The time of one complete cycle is 23.1 seconds, and since the water-hammer wave must travel four times the length of the pipe in one cycle, its velocity is at By comparison, the maximum velocity of flow in the pipe, with one pump in operathe high speed of 4,110 feet per second. tion, is only 2.49 feet per second.

It is, of course, the first super-normal pressure wave that causes most of the pressure wave cannot, however, be negdamage to the pipe line. The subnormal amount of air that can be retained in the lected for it very definitely limits the air chamber.

Water Hammer Waves

In order to explain the method evolved to control the water-hammer pressures, it is necessary to consider first the nature of a water-hammer wave. The magnitude and velocity of the wave depend upon the elasticity of the material composing the pipe wall, the velocity of the water in the pipe and the time in which that velocity or part of that velocity is extinguished. The yare independent of pressure in the pipe and flow velocity, except that part of the velocity that is extinguished. The water-hammer pressure or excess pressure is the variation above or below normal caused by the water-hammer wave. In this case (and in other cases where conditions are similar) the momentum ceases to deliver water almost instantly. The suction line being of the rotating parts of the pump and motor is so small in comparison with the load that when the switch is opened the pump short, no high pressure of any duration is developed in it that might force water through the pump. As a result the stopping of the pump has for all practical purposes the same effect as almost instantaneously closing a valve.

An Analysis

This effect can be examined best by considering the pipe line to be divided into a large number of very small sections of equal length.

When a valve at the inlet end of a pipe in which water is flowing is instantaneously closed, the velocity of the water in the section adjacent to the valve (in this case the pump), is immediately extinguished. This causes the water in this first section to expand, the pressure to fall and the pipe to contract. In other words, the kinetic energy of the moving water has been converted into potential energy. The water in the first section being at rest or static, the velocity of the water in the second section must necessarily cease. The water in the second section then expands, the pressure falls and the pipe contracts in the same manner as in the first section. This reduction in pressure in the second section in no way affects the pressure in the first section for the pressure in that section, excepting gravity and friction, is dependent entirely upon the destruction of the kinetic energy of the water in that section. And, the kinetic energy of the water

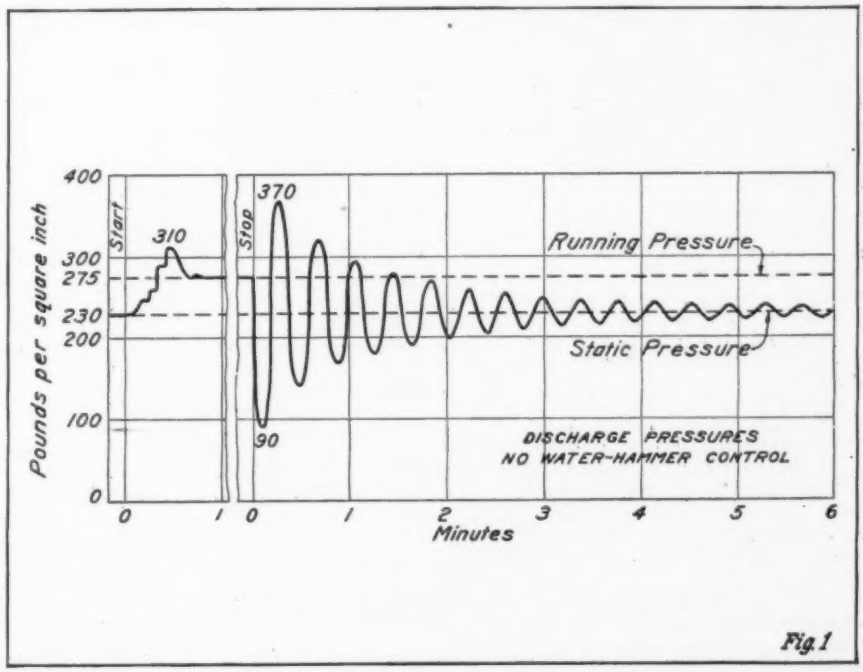


Fig. 1.—Typical Pressure Wave Graph
(One Pump Thrown Out; Relief Valve and Air Chamber Shut Off At the Time)

in the second section is exactly the same as that of the water in the first section and its destruction therefore produces exactly the same reduction of pressure. This process continues through the third, fourth and other sections of the pipe until all the water in the line has expanded, the entire pipe line contracted and the pressure throughout fallen by the same amount. The wave has traveled the length of the pipe once and the water is at rest.

This condition, however, is not stable. The water in the lower end of the pipe can-freeto contract. This it does immediately. not move, but the water inthe upper end is The water in the upper section contracts, the pressure rises and the pipe expands. As a result of this contraction of the water and the expansion of the pipe in the upper section, water flows into the pipe. Conditions in the upper section having thus changed, the second or adjacent section is free to move. The water in the second section then contracts, the pressure rises and the pipe expands. This draws more water into the pipe. In a like manner similar changes occur in the third, fourth and other sections until all the water in the line has again contracted, the entire pipe line expanded and the pressure throughout risen to the point (excepting friction at which it was before the valve was closed or the pump stopped. The wave has traveled the length of the pipe twice. The water is in motion and is flowing toward the pump with the same velocity, excepting for friction losses, at which it was flowing away from the pump before the pump was stopped.

This flow cannot continue, for while the wave has been traveling twice the length of the pipe, ample time has elapsed (11.5 seconds in this case) for the check valve at the pump to close tightly. The flow is therefore directed toward a closed valve and the velocity in the first section adjacent tothe check valve is instantly extinguished. The water in this section is compressed, the pressure rises and the pipe expands. The water in the first section being at rest, the water in the second section must necessarily come to rest with the same changes in condition as occurred in the first section. In a like manner, the water in the third, fourth and other sections come to rest successively until all the water in the pipe line is at rest and compressed, the pressure above normal and the pipe expanded for its entire length. The wave has traveled three times the length of the pipe and the water is once more at rest.

Again, however, the conditions are unstable. The water in the lower end of the pipe cannot move but that in the upper end is free to expand. This it does immediately. The water in the first section expands, the pressure falls and the pipe contracts causing water to flow out of the upper end. Conditions having changed in the upper or first section, the second section is free to move. The water in the second section then expands, the pressure falls and the pipe contracts causing a further flow of water out of the upper end of the pipe. Similar changes occur in the third, fourth and other sections of the pipe until all the water in the pipe has expanded, the entire pipe line contracted and the pressure (except for friction losses) fallen to the normal running pressure. The wave has traveled the length of the pipe four times. The water is moving away from the pump with the same velocity, excepting friction losses, that it was before the pump was stopped. In other words, one cycle has been completed, and conditions are the same as when the pump was running.

The cycle repeats itself until the friction gradually damps out the wave.

A diagram of the effect of this wave near the pump is shown in Fig. 2. The complete cycle is from A to G. The slope of the line from B to C is due to the fall in friction pressure as the wave passes up the pipe and the water gradually comes to rest.

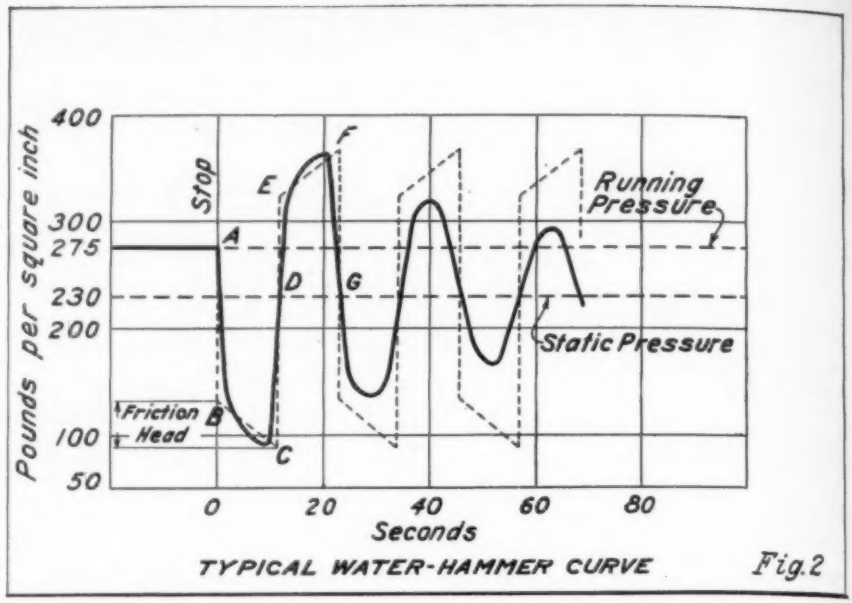


Fig. 2.—Graph of Wave Near the Pump (Explanation of Significance in Text)

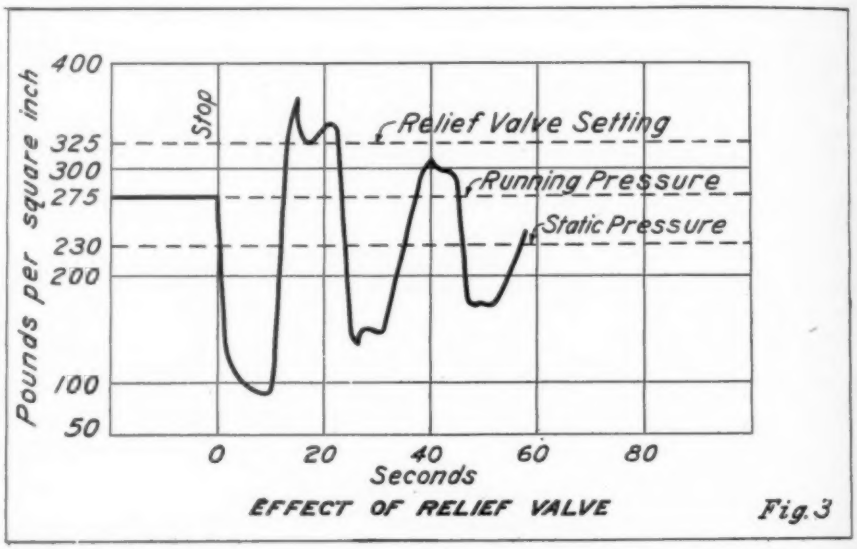


Fig. 3.—Graph Revealing Failure of Spring-Loaded Relief Valve to Relieve

The slope from E to F is due to the rise in friction pressure as the velocity away from the pipe is gradually regained.

A comparison of the velocities and pressure as observed and those computed by Joukovsky's formula (Jour. Am. Water Works Assoc., 1904, p. 341); (W. W. and S., April, 1938, p. 338) is interesting.

Joukovsky's formula for waterhammer, produced by instantaneous valve closure, is:

$$H = \frac{aV}{g}$$

$$a = \frac{12}{\sqrt{\frac{w}{g}\left(\frac{1}{K} + \frac{D}{Ee}\right)}}$$

H = Head due to water-hammer, ft.
a = Velocity of water-hammer water, f.p.s.
V = Velocity of water in pipe, f.p.s.
g = Acceleration of gravity.
w = Weight of one cubic foot of water.
K = Bulk modulus of elasticity of water, pounds per sq. in.
E = Modulus of elasticity of pipe material, pounds per sq. in.
D = Diameter of pipe, inches.
e = Thickness of pipe wall, inches.

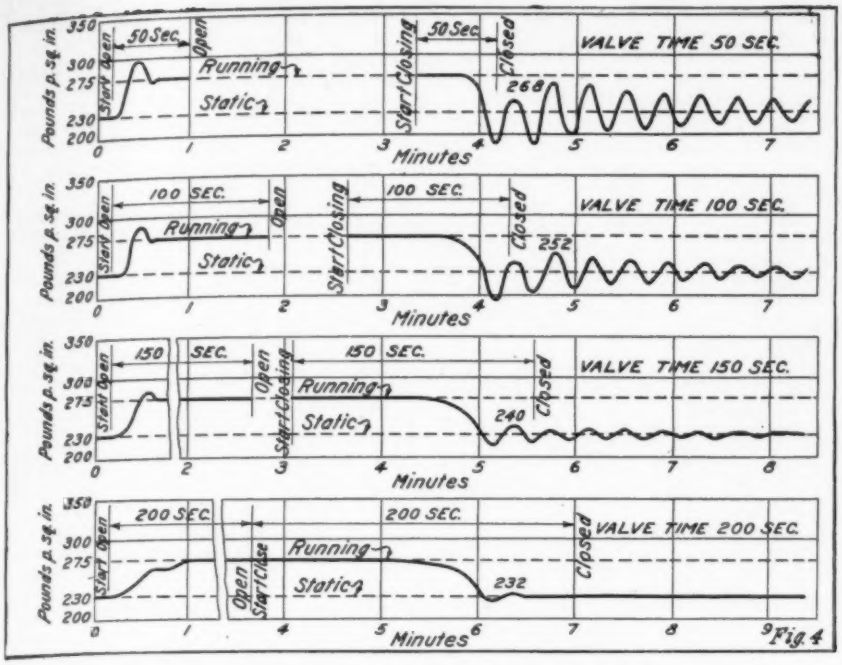


Fig. 4.—Graph Showing Results With a Cone Valve

The value of studying the effects of various closure times for surge suppression is effectively revealed in the four recorded graphs. A splendid testimonial as to the efficacy of properly controlled cone valves

The results are as follows:

Computed water-hammer head (negative)	326 ft.
Observed water-hammer head (negative)	322 ft.
Computed velocity of water-hammer valve	4220 f.p.s.
Observed velocity of water-hammer wave	4110 f.p.s.

If the pipe line had been shorter or the time of stopping longer so that the water-hammer wave set up by the first reduction in the discharge of the pump could have traveled to the end of the pipe and returned to the pump before the flow through the pump had stopped the returning supernormal wave would have interfered with the subnormal wave and the magnitude of the wave would have been reduced. So long as the returning wave does not reach the pump until its discharge is entirely stopped

$$t < \frac{aL}{2}$$

the result, for all practical purposes, is the same as that produced by an instantaneously closed valve. If it does return before the pump discharge has ceased, the interference of the waves must be considered. Except for this interference, the *water-hammer pressure is independent of the length of the pipe.* In the suction line which is only 400 feet long, the first wave returns in 0.2 of a second and interferes with the following waves, preventing, as stated before, the development of a pressure in the suction that might force water through the pump.

Relief Valves

When the Chazy Lake pumping station was built, a 4-inch spring loaded relief valve was installed on the 8-inch discharge line for the purpose of preventing any undue rise in pressure. This relief valve failed to produce the desired result. The effect of the relief valve on the water-hammer pressures shown in Fig. 3. The inertia of the moving parts in the valve apparently prevents it from opening rapidly enough to relieve the pressure and the head rises almost to the same value that it does without the valve in operation. When it finally does release the water the pressure falls to that for which the valve is set. The valve then closes and stops the flow of water through it. The stopping of this flow sets up another water-hammer wave and the pressure again rises.

In order to satisfactorily prevent high pressures by means of a relief valve, the valve must open *before* the first returning wave reaches the pump. That is, before the pressure reaches the point D in Fig. 2. At this time the water in the line is flowing toward the pump and the pressure is the normal static pressure. If the valve is open at this time the water will flow out of the valve with no material rise in pressure. The valve must close slowly or the stopping of the flow through the valve will set up another water-hammer wave with consequent high pressures. It is generally necessary to provide an auxiliary source of power if this method of preventing high pressures is used because the pressure in the lin eis subnormal at the time the valve must start to open and usually insufficient to operate any type of valve.

This arrangement is used effectively at the Dalecarlia Pumping Station, Washington, D. C. (Water Works and Sewerage, April, 1938, Page 353).* In this case the relief valve is of the hydraulically operated rotary plug type and the power for opening it is obtained from an independent water main near the station.

Air Chambers

The 8-inch by 96-inch air chamber provided on the discharge line from the pumps was found on test to be of absolutely no value in reducing the water-hammer pressures, and computations by the graphic method of Prof. Angus indicated that no reduction could be expected. An air chamber on the discharge line of a pump acts by supplying water to the line in gradually decreasing quantities after the pump has stopped, causing a gradual reduction in the velocity in the line instead of a sudden closed valve.

To prevent high pressures in a pipe line by closing a valve slowly instead of rapidly requires that the time of closing be considerable, and if an air chamber is to be effective it must supply water to the line for a considerable time. Not only must the air chamber be large enough to contain sufficient water to

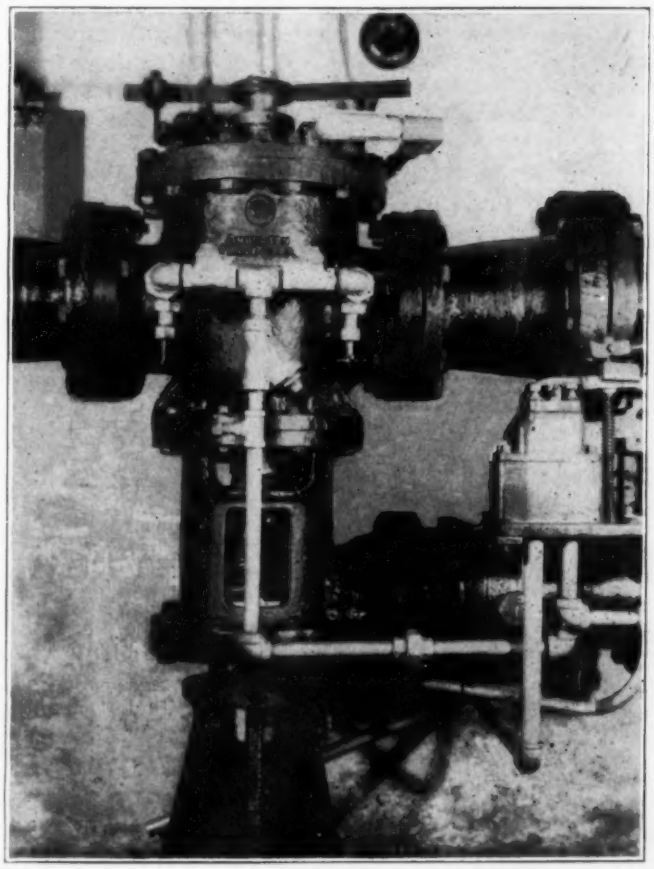


Fig. 5.—The Cone Valve

Which, with proper setting for closing time has solved the water-hammer problem

maintain this supply over the necessary period, but there must be sufficient air above the water to maintain the proper pressure on the water as the air expands. Air chambers, if they are to produce any measurable effect, must be far larger than those usually provided and often so large as to be impractical. Tests are now being conducted at the pumping station of another institution to determine the effects of air chambers of different sizes, but the results must await later publication.

Cone Valve in Discharge Solves the Problem

The method now used at the Chazy Lake pumping station to eliminate the high water-hammer pressures is to reduce slowly the velocity in the discharge line before the pump being used is stopped—this instead of allowing velocity to be suddenly extinguished by the stopping of the pump. This is accomplished by a 6-inch hydraulically operated cone valve located in the main 8-inch discharge line near the pumps (see picture). The cone valve is in closed position when the pump is started. Since a centrifugal pump requires the smallest amount of power when operating against a closed valve, the motor thus starts under minimum load. As soon as the pump reaches its normal speed the cone valve slowly opens, the time of opening being controlled by the setting of a needle valve on the water feed-line to the hydraulic cylinder operating the cone valve. When it is desired to stop the pump the cone valve is first closed slowly, gradually reducing the velocity in the discharge main. After the valve is entirely closed the pump is stopped in the ordinary manner. Electrical interlocks are provided so that the attendant cannot change the order of the operations.

Results

The results of this method of operation, for different timings of the valve, are shown in F : 4. This valve rises from its seat before turning and reseats : self after completing its rotary motion. The time given for opening and closing is the time taken for the valve to rotate through 90 degrees, and does not include the time taken for unseating and seating. There is some leakage past the plug when it is raised from its seat, and the stoppage of this leakage by the seating of the valve in some cases causes a slight secondary wave, as is noticeable in some of the curves. The destruction of the velocity in the pipe line is, of course, not proportional to the amount of rotation of the valve as is evident from the fact that the first 2/3 of the revolution produces no measurable effect on the pressure. The effective closing time is therefore only a fraction of the actual closing time. Setting the valve to close in 50 seconds keeps the water-hammer pressure below the running pressure. Further, increasing the time of closing reduces the water-hammer pressure until with a closing time of 200 seconds the excess pressure caused by water-hammer is scarcely noticeable.

At this pumping station only one pump should be operated at a time if economical results are to be obtained. Two pumps can, however, be operated at once with a consequent decrease in the delivery per pump and a decrease in efficiency. The water-hammer pressure produced by closing the cone valve with two pumps in operation is practically the same as that produced by closing the valve with one pump in operation, the time of closing being the same. The reason for this is that while the actual closing time is the same, the effective closing time, as indicated by the curves, is about twice as long with two pumps in operation.

This method of reducing water-hammer pressures does not protect the discharge line from water-hammer pressures due to power failure. Such protection can be afforded only by a properly timed relief valve operated by a separate source of power or by the use of an air chamber, both of which methods have been station, neither of these methods seemed practical because of the previously mentioned. In the case of the Chazy Lake pumping difficulty of securing a separate source of hydraulic or other power; and, the very large size of the air chamber required to produce even a small reduction in the excess pressure. At this station the water-hammer pressures do not rupture the pipe but do strain the lead joints, and the high pressures can be repeated several times before leaks occur. For these reasons, it was decided to protect the pipe line against the high pressures produced by the daily starting and stopping of the pumps, and to risk occasional high pressures due to power failures which may occur at very infrequent intervals.

Hazleton Type "M"

CHECK VALVE

with Built-in Mercoid Motor Shut-off Switch for Automatic Pump Protection

PROTECTS PUMP FROM DAMAGE DUE TO LOSS OF WATER

PREVENTS OPERATION OF PUMP UNTIL PROPERLY PRIMED

The purpose of the flow switch is to insure pump against damage in the event that the pump loses its water during operation. The mercoid switch is actuated by the valve flap. Normally the switch is open when the flap is down. When the pump delivers water, the flow through the valve raises the flap and closes the switch. The mercoid switch is connected into the no-voltage coil of the motor starter.

When using a hand starter, the pump can be started up by hand, whether delivering water or not, but when the hand is removed from the starting lever, the pump will immediately stop unless the pump is delivering water and the mercoid switch of the check valve closed. With an automatic starter the "start" push button must be held in until the pump delivers water and closes the check valve switch.

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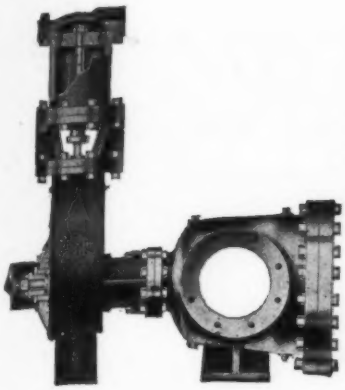
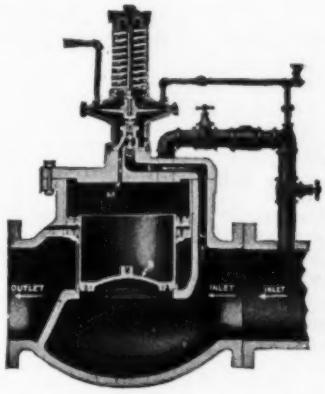


THRU-FLOW CONE VALVE

Afford full pipe line flow without friction loss. Always oil lubricated. Axially unseats before it rotates without friction, rub or wear. Especially desirable for sewage disposal service.



ALTITUDE CONTROL VALVE

Assures uniform water level in tanks, standpipes and reservoirs. Suitable for use in single or two-way line service. Heavy internal bronze mounting and air and water cushioning makes valve indestructible. Sizes to 24".

CUSHIONED FLOAT VALVE

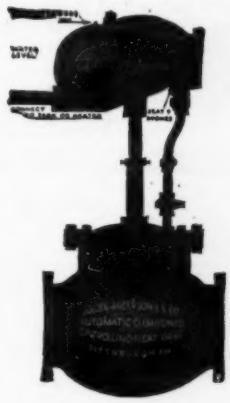
Automatically maintain uniform water levels in tanks, standpipes, etc.

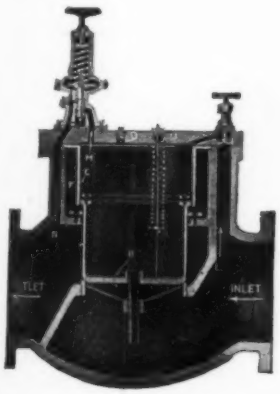
Instantly adjusted to operate quickly or slowly.

Cushioned by water and air, sizes ½ to 24".

CONTROLLING FLOAT VALVE

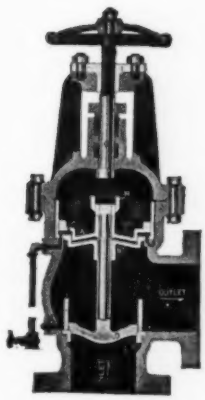
Ideal for heaters, vats, tanks, etc. Valve entirely self-contained and operates without water spill. Sensitive in operation and indestructible due to air and water cushioning and heavy bronze mountings. Sizes to 24".





WATER REDUCING VALVE

Assures positive control of low pressure. Air and water cushioning prevents shock or hammer. Supplied with single or dual pilot controls for any service. Sizes to 24".

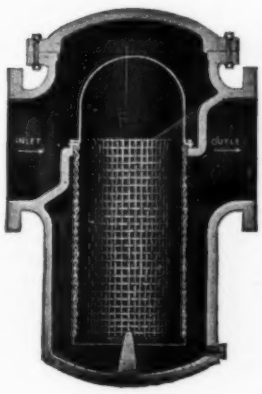


NON-RETURN VALVE

Protect life and property against boiler tube ruptures; also, furnished in Triple Acting style to protect against steam line breaks. Supplied for low and high pressure steam service. Sizes to 12" in angle, globe or elbow patterns.

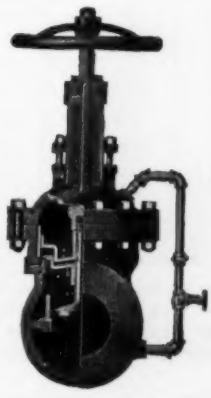
WATER STRAINER

Large capacity with minimum friction loss. Strainer basket quickly accessible and easily cleaned. Basket mesh furnished to suit any service conditions. Sizes to 24".



ENGINE STOP VALVE

The most efficient and dependable automatic stop valve to prevent overspeeding of turbines, engines, etc. Automatically tripped by mechanical or electrical control. Furnished angle or globe patterns to 12" sizes.



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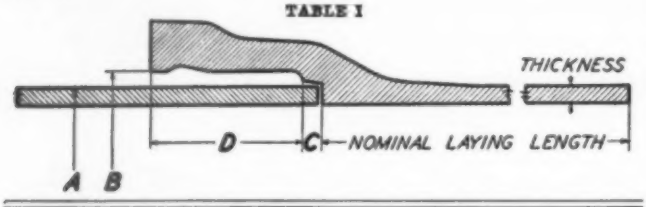
FLANGED PIPE AND FITTINGS
FLEXIBLE JOINT PIPE
LARGE CASTINGS TO ORDER
USICAST CAST IRON ROOF

Super-deLavaud Pipe with B&S Joints

Super-deLavaud Pipe with bell and spigot joints is available in all sizes from 3" to 24" and in 12-foot and 18-foot lengths. The joint is particularly adaptable for lead, cement, joint compound or rubber ring assembly. The centering ring insures easy alignment and uniform distribution of the jointing material. The process by which this pipe is produced assures concentricity, evenness of metal and freedom from sand or slag inclusions. The bell and spigot joint, made with lead or other jointing materials, shows ample strength to resist pulling apart. If required to meet service conditions, pipe will be furnished with special linings. All Super-deLavaud Pipe with bell and spigot joints are made to meet Federal Specification WW-P-421. Write for descriptive booklet.

TABLE I



Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length			
			12-Foot Length		18-Foot Length	
			Weight of Pipe Pounds	Weight Per Foot Including Bell	Weight of Pipe Pounds	Weight Per Foot Including Bell
3	150	.33	140	11.8	210	11.7
3	250	.36	155	12.8	230	12.7
4	150	.34	195	16.4	285	15.9
4	250	.38	220	18.4	325	17.9
6	150	.37	315	26.3	460	25.5
6	250	.43	350	29.3	515	28.5
8	150	.42	475	39.4	690	38.3
8	200	.46	510	42.4	745	41.3
8	250	.50	545	45.5	800	44.3
10	150	.47	640	53.3	935	51.8
10	200	.52	700	58.3	1025	56.8
10	250	.57	760	63.3	1115	61.9
12	150	.50	810	67.4	1180	65.6
12	200	.57	905	75.4	1325	73.7
12	250	.62	990	82.5	1450	80.7

Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length			
			12-Foot Length		18-Foot Length	
			Weight of Pipe Pounds	Weight Per Foot Including Bell	Weight of Pipe Pounds	Weight Per Foot Including Bell
14	100	.48	920	76.5	1340	74.3
14	150	.55	1060	88.5	1555	86.3
14	200	.62	1190	99.0	1735	96.3
14	250	.69	1320	110.0	1930	107.3
16	100	.52	1130	94.2	1645	91.4
16	150	.60	1320	110.2	1935	107.4
16	200	.68	1490	124.1	2175	120.7
16	250	.75	1635	136.1	2390	132.7
18	100	.56	1365	113.8	1990	110.6
18	150	.65	1595	132.8	2330	129.6
18	200	.74	1810	150.9	2645	146.9
18	250	.83	2015	168.0	2950	163.9
20	100	.58	1585	132.0	2305	128.0
20	150	.68	1860	155.0	2720	151.0
20	200	.78	2125	177.1	3105	172.4
20	250	.88	2365	197.1	3465	192.4
24	100	.64	2085	173.8	3035	168.6
24	150	.76	2480	206.8	3630	201.6
24	200	.88	2855	237.8	4170	231.6
24	250	1.00	3200	266.8	4690	260.6

Threaded Cast Iron Pipe Centrifugally Cast

Super-deLavaud Cast Iron Pipe is now being manufactured in "iron pipe sizes" with threaded joints to meet the demand for a better and more durable pipe. There are two distinct types of service for which Super-deLavaud Cast Iron Pipe may be used: pressure service for water, gas, steam or similar liquids and gases; and drainage service. Pressure pipe is made to meet the requirements of Federal Specifications WW-P-421 and is supplied in three classes: standard, extra-strong and double-extra-strong. Drainage pipe, used for waste, vent and drain work, is a lighter pipe for use in buildings and elsewhere where a tight screw-coupled joint is needed. Drainage pipe is made to meet the requirements of Federal Specifications WW-P-356.

THREADED CAST IRON PRESSURE PIPE

(Made to meet the requirements of Federal Specifications WW-P-421)

Size Inches	Class	Nominal Length, Feet	Outside Diameter, Inches	Nominal Thickness, Inches	Threads per Inch	Weight per Foot Pounds
3	Standard	12	3.50	.36	8	11.08
	X-strong	12	3.50	.45	8	13.45
	XX-strong	12	3.50	.48	8	14.21
	Standard	18	4.50	.38	8	15.34
	X-strong	18	4.50	.48	8	18.91
	XX-strong	18	4.50	.52	8	20.29
	Standard	18	5.56	.40	8	20.22
	X-strong	18	5.56	.49	8	24.40
	XX-strong	18	5.56	.53	8	26.15
	Standard	18	6.63	.43	8	26.13
	X-strong	18	6.63	.51	8	30.59
	XX-strong	18	6.63	.55	8	32.78
	Standard	18	8.63	.50	8	39.85
8	X-strong	18	8.63	.56	8	44.29
	XX-strong	18	8.63	.60	8	47.22

THREADED CAST IRON DRAIN PIPE

For Waste, Vent and Drainage Service

(Made to meet the requirements of Federal Specifications WW-P-356)

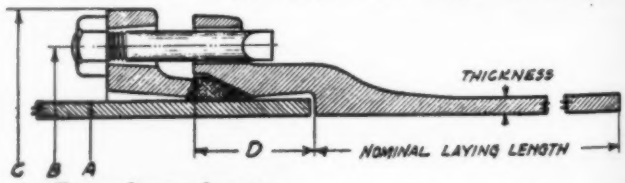
Size Inches	Nominal Length Feet	Outside Diameter Inches	Minimum Thickness Inches	Threads per Inch	Weight per Foot Pounds
3	12	3.50	.26	8	9.41
4	18	4.50	.29	8	13.75
5	18	5.56	.33	8	19.05
6	18	6.62	.38	8	26.22
8	18	8.62	.44	8	39.82

THE U. S. JOINT

The U. S. Joint embodies the more favorable features of certain other types of mechanical joints and was developed and patented by the United States Pipe and Foundry Company after considerable study and research. It is adaptable to both Super deLavaud Centrifugal Pipe, and to pit cast pipe and fittings and these may be interchanged one with another in the laying of a line without the need of an adapter. The accessories, which consist of follower ring, gaskets and bolts are all interchangeable.

It possesses the following salient advantages:

Write for "U. S. Joint Pipe and Fittings" Catalog.



1. Ruggedness of parts.
2. High resistance to corrosion since all of the joint accessories are of the same material—cast iron.
3. Maximum joint deflection without leakage.
4. Great resistance to the flow of electric currents.
5. Ease of assembly—needs only one wrench.
6. Only one gasket per joint.
7. Excellent qualities as an expansion joint.
8. Tightness under high pressures of gas or water.
9. Connection to plain end existing pipe line without use of adapter.

THE HARDY CROSS METHOD

Its Practical Application in Determining Flows and Heads in Pipe Systems

By D. R. TAYLOR*

Superintendent, Roanoke Water Department, Roanoke, Virginia

Fundamentals and Elementary Use

SINCE the first water pipe system of bored logs was installed, water works engineers and operators have sought a simple and sound method of evaluating quantities of flow and resulting heads in pipe systems. Many methods have been devised, most of which have been either highly technical, or too cumbersome or onerous.

A few years ago Hardy Cross, then Professor of Structural Engineering at the University of Illinois and now Professor of Civil Engineering at Yale University, devised and produced a method that was welcomed by engineers and operators and one that was and is being rapidly adopted as "the method." The method in detail was published in 1936 by the University of Illinois Experiment Station—"Analysis of Flow in Networks of Conduits and Conductors," Bull. 286.

Many conversions and adaptations of this method have been advanced, all of which have merit. Of especial merit is the simplified system presented by James J. Doland, Professor of Civil Engineering, University of Illinois. The main attractiveness of the Doland modification is that the determinations are for percentages of total flow and therefore, after calculations for any particular pipe network have been made, they may be applied to any quanities of flows without recalculating the system, provided, of course, that the take-offs (illustrated later) remain proportionate.

The Hardy Cross Method is based on fundamentals, is absolutely sound and is simple and convenient to use when properly understood. It is the purpose of the author to present an explanation and simple practical examples of the Doland system using the Hardy Cross Method.

To Begin at the Beginning

Although the method is applicable to any of the flow formulas, the system herein presented is based on the Hazen and Williams formula.

While an assumption must be made at the beginning, it does not have to be even a good one, because one of the inherent characteristics of the method is that it reveals whatever error there may be in the first assumption in an exact percentage, making the second trial factual in every respect.

It is a well understood fundamental, that if a flow is divided between two pipes of equal size, length and smoothness, that the same quantity will flow through each pipe and that the friction loss in each pipe will be equal. This is illustrated in Fig. 1.

Another fundamental is that if the two pipes are of *different* diameter, length and smoothness, that such a quantity will flow through each pipe, that will produce the same total friction loss in each pipe. Calculating these quantities has heretofore been difficult to determine, but the Hardy Cross Method answers these questions simply and with the least amount of effort on the part of the explorer.

Nomenclature

The following nomenclature will be used:

d = diameter in inches
D = diameter in feet
Q_m = quantity of flow in gallons per minute
Q_d = quantity of flow in gallons per day
S = friction loss per 1000 feet
S_t = total friction loss for any length
r = a resistance factor, depending upon size and smoothness of pipe
k = 100,000 r (100,000 times r)
h_f = a friction loss factor
H = head in feet
C = coefficient of friction
P = pounds per square inch

*Since the writing of this article the author has entered the Army as Captain of the U. S. Engineers, assigned to duty with the Fourth Service Command.

Fundamental Formulas

(1) $$S = r\ Q_m^{1.85}$$

(2) $$r = \frac{S}{Q_m^{1.85}}$$

(3) $$k = 100{,}000\ r$$

(4) $$k \times Q_m^{0.85} = kQ_m^{0.85}$$

(5) $$kQ_m^{0.85} \times Q_m = h_f$$

(6) $$S_t = \frac{\Sigma\ (\text{sum of})\ h_f}{100{,}000}\ (0.01\ Q_m)^{1.85}$$

(7) $$Q_d = 1440\ Q_m$$

An Example of Application

Assume an 8 in. pipe with C = 110 and Q_m = 695 (one million gallons per day). Prove formulas 2, 5 and 6.

From Hazen and Williams tables S = 12.7 feet.

$$\text{By (2)}\quad r = \frac{12.7}{(695)^{1.85}}$$

$$= \frac{12.7}{180{,}990}$$

$$= .00007$$

The values of r being such large and cumbersome fractional numbers, for convenience they are multiplied by 100,000 and the resulting values called (k).

These k values are tabulated in Figure 2. [For instance, .00007 × 100,000 = 7, which is k for 8" pipe having a C value of 110.]

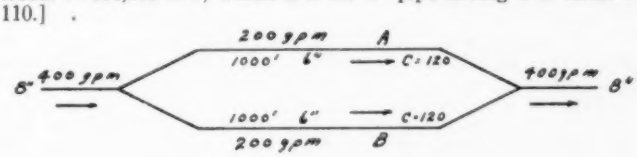


Fig. 1—Balanced Flow

Figures 13, 14, 15 and 16 give values of exponential powers of numbers sufficiently close for practical use. For extreme accuracy (academic use) logarithms or cologarithms may be used (see tables 146 and 147 Handbook of Hydraulics, Horace W. King, 1939).

Fig. 2—Values of k for 1000 Feet of Pipe Based on the Hazen-Williams Formula

Pipe Diameter, Inches	C = 90	100	110	120	130	140
4	300	248	208	177	153	133
6	41	33.7	28.4	24.2	20.9	18.2
8	10	8.4	7.0	6.0	5.2	4.5
10	3.4	2.8	2.4	2.0	1.7	1.5
12	1.5	1.2	1.0	.83	.71	.62
14	.66	.55	.46	.39	.34	.30
16	.35	.29	.24	.20	.18	.15
18	.20	.16	.14	.12	.10	.09
20	.12	.10	.08	.07	.06	.05
24	.049	.04	.03	.03	.02	.02
30	.016	.013	.011	.010	.008	.007
36	.0067	.0054	.0046	.0039	.0034	.0030

Fig. 2

Using the assumed values in this example, in which 100 per cent of the flow is through the pipe being considered, we find that,

$$Q_m^{0.85} = (100)^{0.85} = 50.12$$

By (5), $h_f = 7 \times 50.12 \times 100$ (k = 7, from fig. 2)
$= 35{,}084$

By (6), $S_t = \dfrac{35{,}084}{100{,}000} \times (6.95)^{1.85}$

$= .35084 \times 36.11$ (fig. 13)
$= 12.7$ feet

Fig. 3—Values of the 0.85 Power of Numbers

N	0	1	2	3	4	5	6	7	8	9
0	0	1.0	1.8	2.5	3.2	3.9	4.6	5.2	5.9	6.5
10	7.1	7.7	8.3	8.9	9.4	10.0	10.6	11.1	11.6	12.2
20	12.8	13.3	13.8	14.4	14.9	15.4	15.9	16.5	17.0	17.5
30	18.0	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5
40	23.0	23.5	24.0	24.5	25.0	25.4	25.8	26.4	26.8	27.3
50	27.8	28.2	28.7	29.2	29.6	30.1	30.6	31.0	31.4	32.0
60	32.4	33.0	33.3	33.9	34.2	34.7	35.1	35.6	36.0	36.5
70	37.0	37.4	37.9	38.3	38.8	39.1	39.6	40.0	40.5	41.0
80	41.5	42.0	42.4	42.8	43.3	43.7	44.1	44.5	45.0	45.4
90	45.8	46.3	46.7	47.1	47.6	48.0	48.4	48.8	49.2	49.6

Fig. 3

This value agrees with that originally taken from the H & W tables.

Procedure

The procedure is this simple: A network of pipes is considered as a group of closed circuits and each circuit is considered to have two loops, either or both of which may consist of several sizes of pipes. A balanced condition (flow) exists only when a force (friction loss) in one loop (for convenience the clockwise force is considered first) is equal to the force in the opposite (counter clockwise) direction. A percentage of the total flow is first assumed to flow around each loop of a closed circuit and the value of h_f, depending upon the quantity of flow, is calculated for each loop. To satisfy the hydraulic fundamental previously mentioned, the friction loss in each loop will be equal if the original assumption as to quantity of flow in each loop is correct. If the assumption is not correct, the calculation reveals the percent of error. It shows the percent of flow to be added or subtracted to or from the first assumption. The same amount added to the flow in one loop must, of course, be subtracted from the flow in the other loop. That is, the flows must be balanced to produce the same friction loss in each loop. This amount, to be added or subtracted, is known as the "correction," or percent of correction.

The corrections are made and the friction head (h_f) for each loop is again calculated and so on, until the amount or percentage of correction is as small as is desired. How small will be determined by the degree of accuracy sought. For usual design (or a study of an existing system) a correction to anything under 1 percent is sufficient, and this is not laborious. In the consideration of a large network it may be necessary to make from three to ten corrections before the conditions of a balanced flow are satisfied.

Professor Cross suggests that a curved arrow be drawn on the right of the values of the sum the two h_f values for each circuit with the arrows pointing from the smaller to the larger figure. Such arrows will show correctly the direction of the counterflow in the particular circuit. In the examples given with this discussion a horizontal arrow indicates the larger figure and direction of counterflow into the circuit represented.

For the simpler problems, the arrow may be omitted. For more complicated problems if one wishes to indicate the direction of the counterflow he may do so with any symbol that is preferred or understood by him.

Preliminary and Working Sketches

In the consideration of a pipe system, it is good practice to first make a diagrammatic plan. A rough pencil sketch is sufficient to begin on. It does not have to be to scale, but need only show the sizes, lengths, pipe coefficients, point of entrance and discharge, etc. Such a preliminary sketch is illustrated in Fig. 4.

Then a second sketch is made, which may be called the working sketch. On this is shown the quantities (percent of total flow) and the values of (k), as illustrated by Fig. 5, and the assumed direction of flow as indicated by arrows.

Illustration of Use of the Method

Refer to Fig. 5. In this case, loop ABCD consists of 3000 feet of 8" pipe with C = 120. From Fig. 2 (the table) we find that (k) for 8" pipe, C = 120 is 6 per 1000 feet. Therefore, k for loop ABCD is 3×6 = 18, which is recorded at a convenient point on the loop in question, as shown on the sketch. Loop AD also being 8" pipe, C = 120, has the same k of 6 per 1000 feet and being 1000 feet in length its k is 1×6 = 6. This value is recorded on this loop A-D. In addition, 100% is shown entering at point A and leaving at point D.

The First Assumption

The quantity of flow around each loop that will produce the same friction loss in each loop is now desired.

Considering that loop ABCD is three times as long as loop AD and that there are four sides of equal length in this closed circuit, it may be logical to assume that only one fourth of the total quantity will flow around loop ABCD and three fourths will pass through "loop" AD. The first assumption will be, therefore, 25% for loop ABCD and 75% for loop AD. These assumed percentages are placed on Fig. 5.

The first assumed percentage of flow is usually shown along and near the center of the length of pipe or loop in question. If this value is found to be incorrect, it may be circled and the corrected value placed above or beside it, as for instance, 25 becomes 36 and 75 becomes 64 upon the first trial—see Fig. 5. If four trials are made in order to balance the flow, there will be three circled values and a final and correct value which will not be circled.

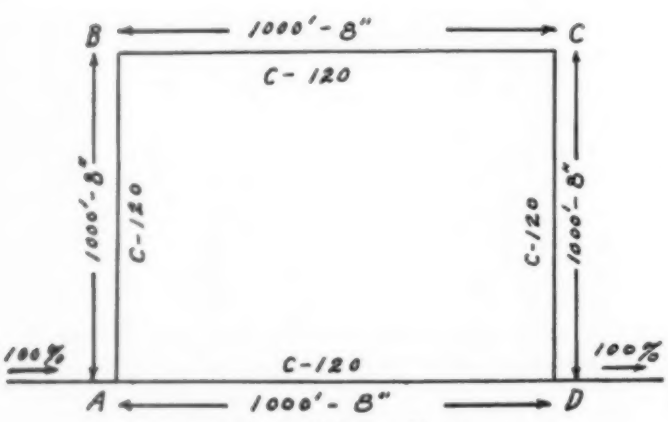


Fig. 4—Preliminary Sketch

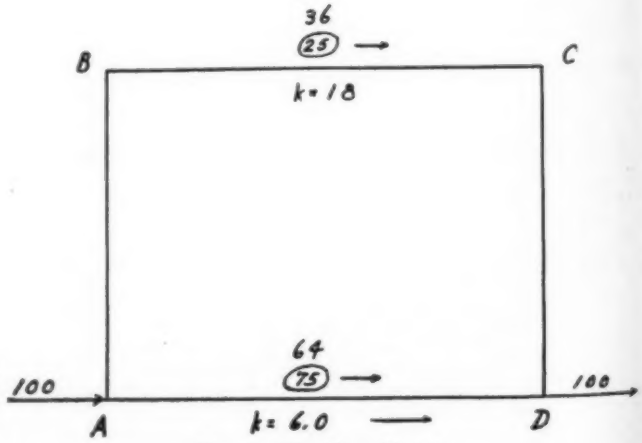


Fig. 5—Working Sketch

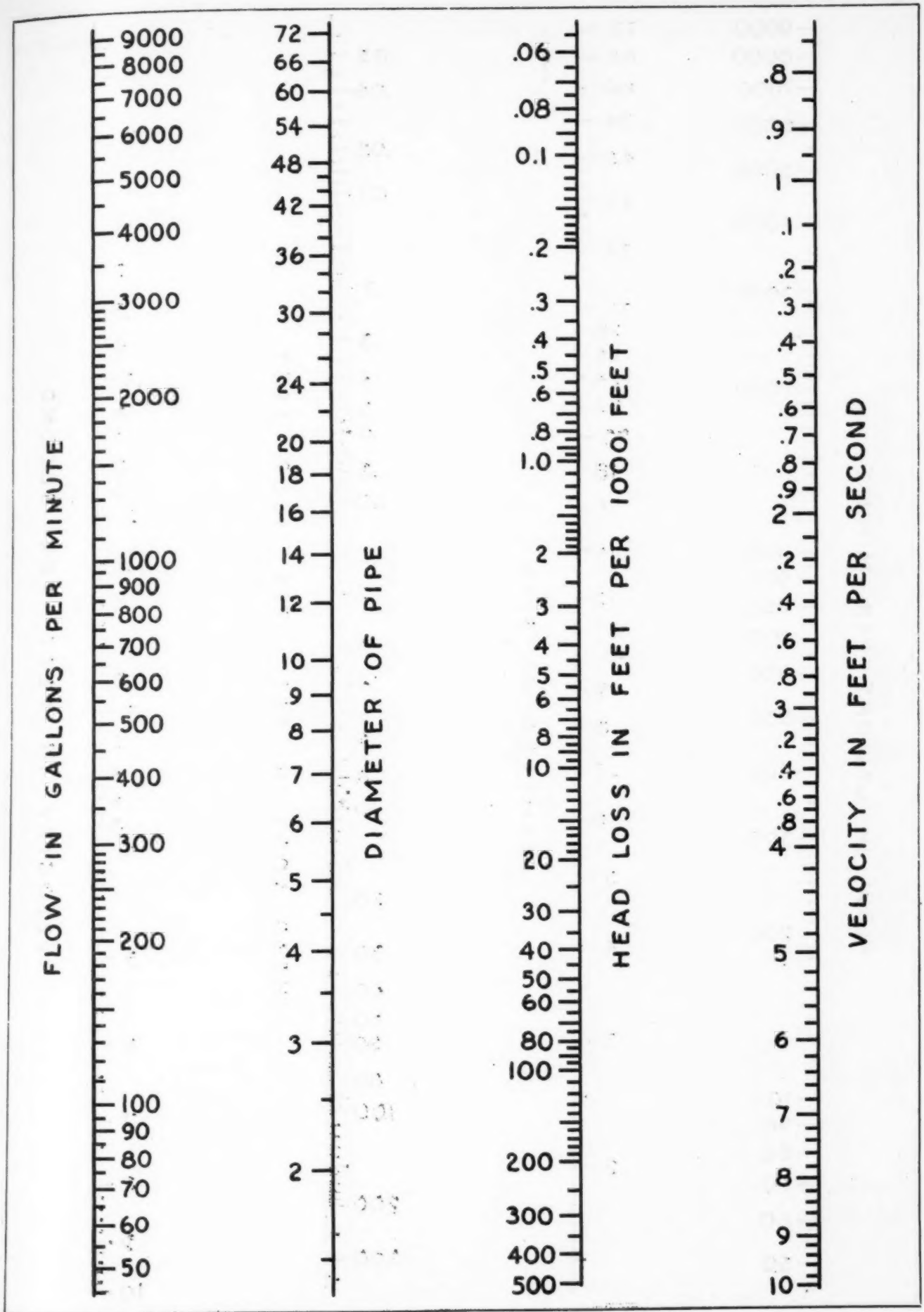


Fig. 6—Flow Chart for C = 100 (Hazen and Williams Formula)

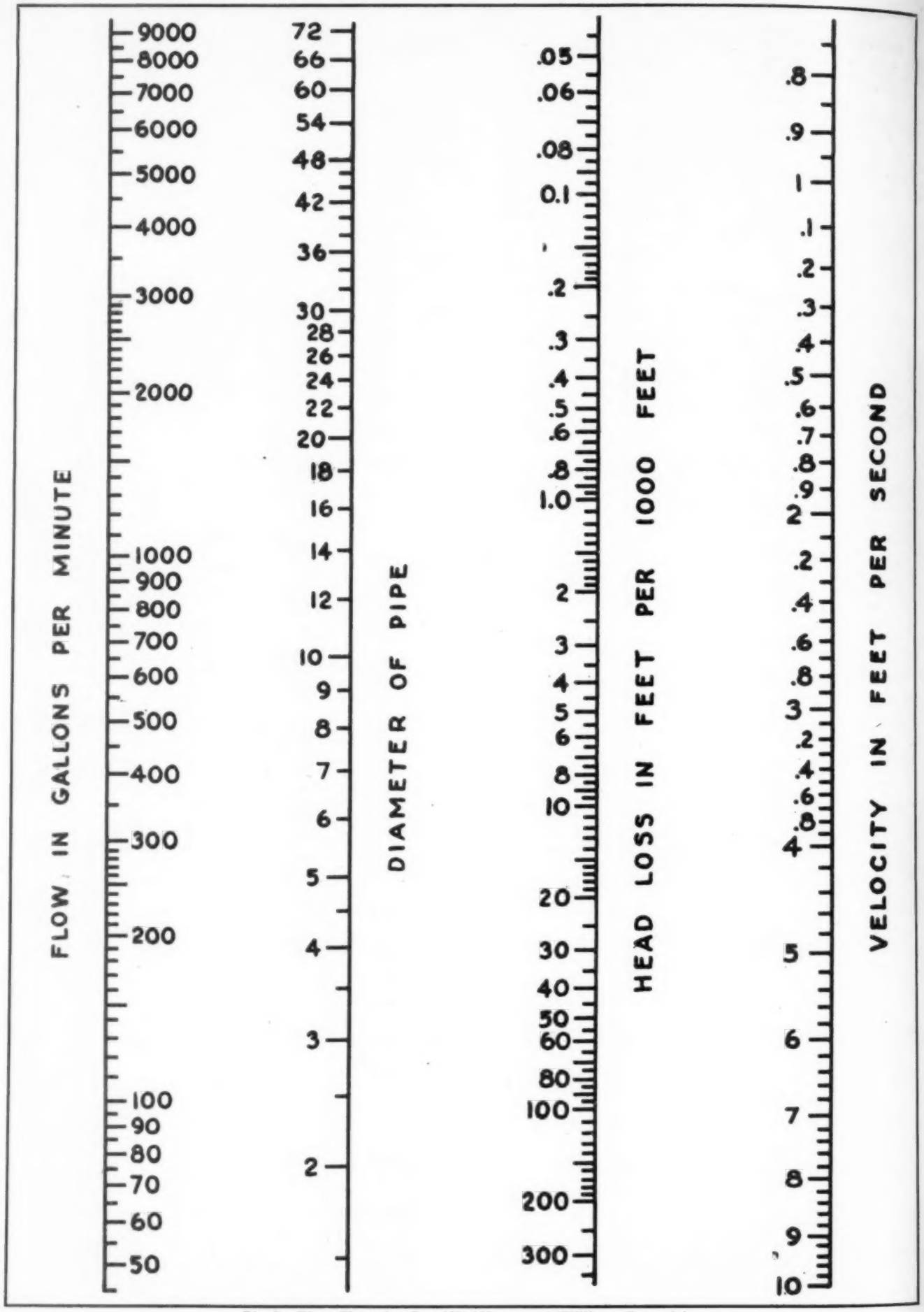


Fig. 7—Flow Chart for C = 120 (Hazen and Williams Formula)

The Calculation

The value of $Q_m^{0.85}$ can be obtained from the table—Fig. 3. The clockwise loop ABCD is considered first.

Loop	$k \times Q_m^{0.85} = kQ_m^{0.85} \times Q =$	h_f
ABCD	$18 \times 15.4 = 277.2 \times 25 =$	6930
AD	$6 \times 39.1 = 234.6 \times 75 =$	17595←
	511.8*	10665**

*Adding the $kQ_m^{0.85}$ values = 511.8
**Subtracting the h_f values = 10665

The amount (percent) of correction to be made is equal to the difference of h_f divided by 1.85 times the sum of the $kQ_m^{0.85}$ values.

$$\therefore \text{Correction} = \frac{10665}{1.85 \times 511.8} = \frac{10665}{946.83} = 11.26\%$$

11% should be subtracted from the assumed quantity through the loop having the greatest h_f value (loop AD) and added to the quantity through the other loop. In other words, the original assumption was 11% too much for loop AD and 11% too little for loop ABCD. For all practical purposes it is not necessary to apply the correction to the extent of using decimal fractions. That is, 11% is enough rather than actually correcting to 11.26%.
75 − 11 = 64 (corrected flow for loop AD)
25 + 11 = 36 (corrected flow for loop ABCD) (see fig. 5)
The first assumption is circled and the corrected flow shown above or beside it. Any convenient method may be used to designate the first assumption and subsequent trials or corrections, such as drawing a line through each, as it is further corrected. The values of k do not change with changes in percentage of flow, but remain constant for all quantities of flow; however, $Q_m^{0.85}$ does change with each change of flow and must be again obtained from table 3 for each correction.

Second Trial

Loop	$k \times Q_m^{0.85} = kQ_m^{0.85} \times Q =$	h_f
ABCD	$18 \times 21.0 = 378 \times 36 =$	13610←
AD	$6 \times 34.2 = 205 \times 64 =$	13110
	583 (sum)	500 (difference)

$$\therefore \text{Correction} = \frac{500}{1.85 \times 583} = \frac{500}{1080} = 0.462\%$$

Since the correction is less than 1%, the second trial proved the first correction was sufficient and brought the loops into balance. It was therefore the final trial. However, in networks consisting of several circuits, it is often necessary to make several trials and corrections before a satisfactory final result is obtained. It is evident that the method is not difficult though.

Determining Total Friction

To obtain total friction loss (S_t) from A to D we first get the average h_f of both loops.

$$\frac{13610 + 13110}{2} = 13355 \text{ (Average } h_f\text{)}$$

For a flow (Q_m) of 695 gpm the total friction loss from A to D in either loops equals—

$$\text{By formula (6) } S_t = \frac{13355}{100{,}000} (0.01 \times 695)^{1.85}$$
$$= .1335\ (6.95)^{1.85*}$$
$$= .13355 \times 36.1*$$
$$S_t = 4.82'$$

(*Note these values obtainable from Fig. 13.)

The friction loss S_t from A to D is therefore 4.82 ft. of pressure head.

With formula (6) total friction loss (S_t) between any two points for any quantity of flow (Q_m) may be calculated without further reference to or work with the working sketch (Fig. 5). In other words, after the flows have once been balanced, total friction losses may be obtained for any possible flow by only using formula (6). No further balancing is necessary.

Proving the Method

With $Q_m = 695$ g.p.m.
36% of 695 = 250 g.p.m.
64% of 695 = 445 g.p.m.
Referring to Flow Chart (Fig. 7C—120)
With d = 8, $Q_m = 250$, S is equal to 1.625′ per 1000 feet
With d = 8, $Q_m = 445$, S is equal to 4.700′ per 1000 feet
Therefore by the Flow Chart (Hazen-Williams Tables)
S_t for loop ABCD = 3.0 × 1.625 = 4.86′
S_t for loop AD = 1.0 × 4.70 = 4.70′

$$\text{Average } S_t = \frac{4.86 + 4.70}{2} = 4.78'$$

By Hardy Cross Method, $S_t = 4.82'$
Difference = 4.82 − 4.78 = 0.04′

A System of Two Circuits

Many pipe systems to be studied will contain two circuits with at least a part of one loop being a common side to both circuits, as illustrated by Fig. 8.

In this case, the use of a combined sketch showing all data is demonstrated. It is believed that, by now, the fundamentals are so well understood that examples of the calculations will constitute sufficient explanation of the use of the method.

First Trial

Circuit M

Loop	$k \times Q_m^{0.85} = kQ_m^{0.85} \times Q =$	h_f
AB	$3.6 \times 27.8 = 100 \times 50 =$	5000
BE	$2.4 \times 7.1 = 17 \times 10 =$	170
		5170
AFE	$6.0 \times 27.8 = 167 \times 50 =$	8330—8330←
	284*	3160**

*Adding the $kQ_m^{0.85} = 284$.
**Subtracting the h_f values = 3160.

$$\text{Correction } \frac{3160}{1.85 \times 284} = 6.02$$

Circuit N

BCD	$11.2 \times 23 = 258 \times 40 =$	10310—10310
BE	$2.4 \times 7.1 = 17 \times 10 =$	170
ED	$5.6 \times 32.4 = 181 \times 60 =$	10900—11070←
	456	760

$$\text{Correction } \frac{760}{1.85 \times 456} = 0.902$$

In making this correction it should be noted that while circuit M requires a correction of 6%, circuit N requires a correction of only 1%. This means that the flow from A to B should be increased 6% but at point B this flow should be divided between BCD and BE so that the flow in BCD is increased only 1%: therefore, 1% is added to BCD and 5% is added to BE. (See Fig. 8.)

Second Trial

Circuit M

Loop	$k \times Q_m^{0.85} = kQ_m^{0.85} \times Q_m =$	h_f
AB	$3.6 \times 30.6 = 110 \times 56 =$	6165
BE	$2.4 \times 10.0 = 24 \times 15 =$	360— 6525
AFE	$6.0 \times 25.0 = 150 \times 44 =$	6600— 6600←
	284	75

$$\text{Correction} = \frac{75}{1.85 \times 284} = 0.143$$

Circuit N

BCD	$11.2 \times 23.5 = 263 \times 41 =$	10800—10800
BE	$2.4 \times 10.0 = 24 \times 15 =$	360
ED	$5.6 \times 32.0 = 179 \times 59 =$	10560—10920←
	466	120

$$\text{Correction} = \frac{120}{1.85 \times 466} = 0.139$$

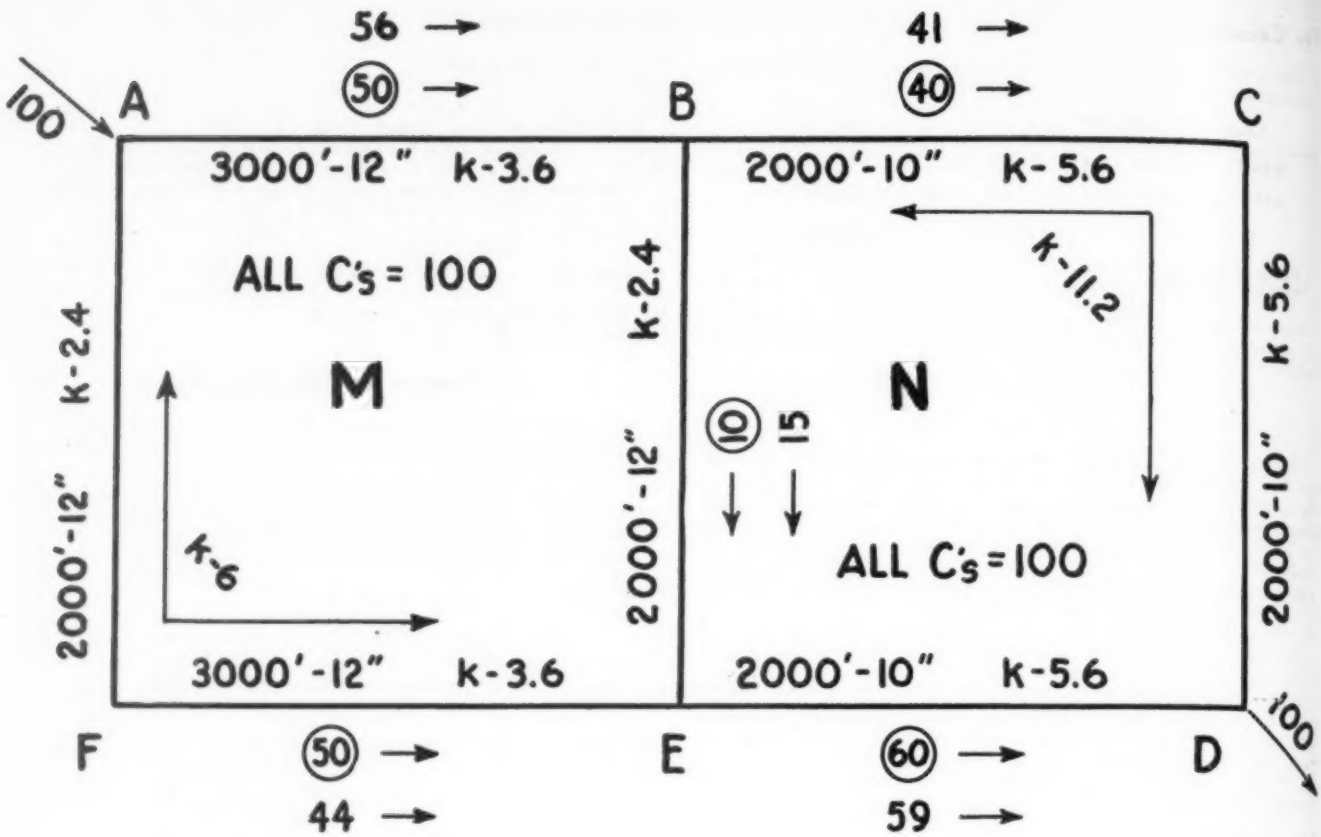


Fig. 8—A System of Two Circuits

To determine S_t from A to E for any Q_m (say 2800 gpm.)

Loop	h_t
ABE	6525
AFE	6600
	13125

$$\frac{13125}{2} = 6562 \text{ (average } h_t\text{)}$$

By formula (6)—

$$S_t \text{ (A to E)} = \frac{6562}{100{,}000} (28)^{1.85}$$
$$= 0.06562 \times 475^*$$
$$= 31.169'$$

(*From chart of $N^{1.85}$ values Fig. 13.)

To determine S_t from A to D with $Q_m = 2800$

Loop	h_t	
AB	6165	
BCD	10800	
		16905
AFE	6600	
ED	10560	
		17160

$$\frac{16956 + 17160}{2} = 17062 = \text{average } h_t$$

By formula (6)—

$$S_t \text{ (A to D)} = \frac{17062}{100{,}000} (28)^{1.85}$$
$$= 0.17062 \times 475^*$$
$$= 81.04'$$

(*From Chart, Fig. 13)

Proving the Method

ABCD
56% of 2800 = 1570
41% of 2800 = 1148
From Flow Chart (Fig. 6-C = 100)
With d = 12, Q_m = 1570, S = 9.6′ per 1000′
With d = 10, Q_m = 1148, S = 13.0′ per 1000′
S_t (AB) = 3.0 × 9.6 = 28.8
S_t (BCD) = 4.0 × 13.0 = 52.0
80.8′

∴ Total friction loss A to D by loop ABCD = 80.8 ft.

AFED
44% of 2800 = 1232
59% of 2800 = 1652
From Flow Chart (Fig. 6-C = 100)
With d = 12, Q_m = 1232, S = 6.0′ per 1000′
With d = 10, Q_m = 1652, S = 25.5′ per 1000′
S_t (AFE) = 5.0 × 6.0 = 30.0
S_t (ED) = 2.0 × 25.5 = 51.0
81.0′

∴ Total friction loss A to D by loops AFED = 81 ft.

$$\text{Average } S_t \text{ (A to D)} = \frac{80.8 + 81.0}{2} = 80.9$$

S_t (A to D) by Hardy Cross Method = 81.04′
by H & W Tables (Chart) = 80.90′
Difference = 0.95′

The above constitutes all of the description necessary to show the fundamentals and the use of the Hardy Cross Method by the Doland System, sufficient for one to practically apply it in the design of a new system or to evaluate an old system. The suffix after Q has been used so far to impress the fact that the formulae herein are all based on Q in gallons per minute. In general practice several variations are used, for instance, the (%) mark, the suffixes m, f and t may be omitted after Q, h and S respectively, and the formulae (4) and (5) may be omitted above the calculations. H is preferred by some instead of h in formulae (1), (5) and (6). The designations that one cares to use are inconsequential; it is the method that is important and valuable.

The method becomes easier with each use. The third time that it is used, the time required may be less by one fourth to one third for a problem of equal size.

For Advanced Practice

For more advanced use and for the solution of more intricate problems more theory is necessary, and it might be well to present an example of a larger design problem.

$$\text{By (2) } r = \frac{S}{Q_m^{1.85}}$$

$$\text{By (3) } k = 100{,}000\ r$$

Therefore,

$$(8)\quad k = \frac{100{,}000\ S}{Q_m^{1.85}}$$

Also

$$(9)\quad k = \frac{1{,}064{,}000{,}000}{C^{1.85}\ d^{4.87}} \quad \text{(see Figure 15)}$$

or for diameter in feet (D),

$$(10)\quad k = \frac{5860}{C^{1.85}\ D^{4.87}}$$

k varies inversely as the 4.87 power of d or D

$$(11)\quad k_2 = k_1 \left[\frac{d_1}{d_2}\right]^{4.87}$$

To avoid confusion, sizes may be designated by a suffix as, for instance, k_6, d_8, etc.

Example: C = 120, d = 10, k = 2.0
Desired, k for d = 8

$$\text{By (11)} \quad k_8 = k_{10} \left[\frac{d_{10}}{d_8}\right]^{4.87}$$

$$= 2.0 \left[\frac{10}{8}\right]^{4.87}$$

$$= 2.0\ (1.25)^{4.87}$$

$$= 2.0 \times 2.962^{*}$$

$$= 5.93 \quad (6.0 \text{ Fig. 2 is close enough})$$

(*From Chart, Fig. 15.)

Figure 9 shows k for various diameters. k varies inversely as the 1.85 power of C.

$$(12)\quad k_2 = k_1 \left[\frac{C_1}{C_2}\right]^{1.85}$$

Example: d = 10, C = 110, k = 2.4
Desired: k for C = 105

$$\text{By (12)} \quad k_2 = 2.4 \left[\frac{110}{105}\right]^{1.85}$$

$$= 2.4\ (1.0476)^{1.85}$$

$$= 2.4 \times 1.09^{\dagger}$$

$$= 2.62$$

(†From Chart, Fig. 13.)

A Practical Problem

A practical example of a design embodying most of the problems encountered in the use of the Hardy Cross Method may be described and illustrated as follows:

A suburban residential area was located at an elevation higher than that which could be served by the regular normal pressure of a city and, therefore, was served by special facilities installed at the beginning of the development when the demands were small. It had grown to proportions which demanded revamping of the system and the addition of fire protection facilities. A distribution system was designed to be used in conjunction with a 250,000 gallon tank and a booster pump of 400 gpm capacity, to be started by a float switch, when the water level in the tank dropped two feet. (See Fig. 10.) All of the old small mains were replaced with larger mains, except the 6" main from I to K, which was paralleled with an 8" main.

Procedure

First an equivalent diameter must be found for the 6" main and 8" main (parallel) from I to K. Fig. 12 shows this equivalent diameter to be 9.26", k for all mains except this equivalent diam-

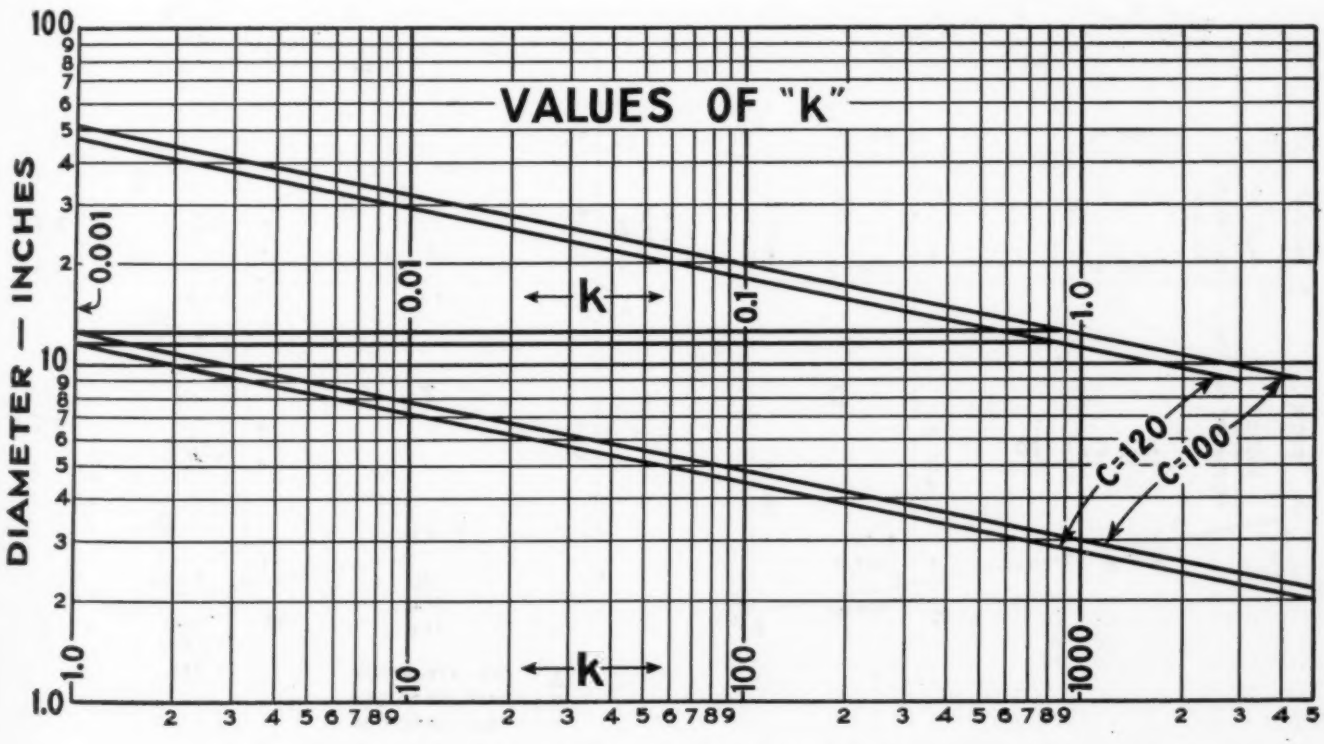


Fig. 9—Values of k for C 100 and C 120 for Pipes of Various Diameters

eter is shown in Fig. 2. For this diameter k may be found in Fig. 9 to be 2.95 (see formula 11).

To find k for two parallel mains that have different coefficients (C), that is, an old tuberculated main and a new main, the procedure is as follows:

Assume any S and determine Q for that S through the one main. Then determine Q for the same S in the other main. Then, from the flow chart, determine what size main will produce the total of the two flows (that of both mains) with the same S and with the C value which it is desired to use in the design.

The maximum domestic consumption was found to be 100 gpm and could be equally distributed between points C, E, G, J and K with a one per cent "take-off" at each of these points. Consumption at points within circuits is usually called a take-off and the quantity used at these points is designated as a percentage of the total flow into the system.

With a total flow of 2000 gpm into the system and with the pump furnishing 400 gpm, 20% would be furnished by the pump and 80% by the tank, the 80% entering the system at point B and 20% entering at I. (See Fig. 11.)

With a conflagration at point F demanding a fire flow of 1900 gpm, what will be the expected residual flow pressure at point F?

This problem embraces four features not previously shown:

1. Flow into the system is at more than one point.
2. There are parallel mains in one street.
3. The system consists of more than two circuits.
4. There are six take-offs in the system.

Example:

C for new main = 120

C for old main = 100

Desired: Equivalent diameter and k.

Flow chart for C = 100 (Fig. 6), with S = 5 feet per 1000′ shows that a 6" main will produce a Q_m of 180 gpm. Flow chart for C = 120 (Fig. 7), with S = 5′ per 1000′ shows than an 8" main will produce a Q_m of 460 gpm.

The total of the two $Q_m = 180 + 460 = 640$.

Q_m for the 6" main was with C = 100 and Q_m for the 88" main was with C = 120. It is desired to use C = 120 for all calculations; therefore, from flow chart with C = 120 it will be seen that for $Q_m = 640$ and S = 5, that d = 9.1".

From Fig. 9, k for 9.1" = 3.25 for C = 120 (also see formulas 11 and 12).

In this case (Figs. 10 and 11) the two parallel mains have the same C value (120) and a value of k = 2.95, which will be used.

Consideration of the Working Sketch

The working sketch (Fig. 11) shows values of k, take-offs of 1% each at points, C, E, G, J and K, 80% entering at point B, 20% entering at point I, a take-off at point F (the location of the conflagration), the values for the first assumption, the first correction and the final correction. Actually seven corrections were required to balance the flows in this system; however, only two corrections are shown. It was not deemed necessary to repeat the process seven times to demonstrate the method. The first assumption is shown within a circle, the first correction within a rectangle and the final correction not enclosed.

Attention should be called to the fact that the sum of the flows leaving a point of take-off should be equal to the flow entering this point, minus the quantity of take-off. For instance, in the first assumption, the flow from B to K is 35%. The take-off at K is 1%, therefore the flows leaving K should equal 34%, as shown. The flow from K to H being 10% and from K to J being 24%, the sum of which equals 34%. It should also be stated that it is often the case that the direction of flow in a loop is erroneously assumed, and should be reversed as well as increased or decreased; however, this is usually indicated plainly enough for immediate detection.

Computations

The computations for Fig. 11 are as follows:

First Trial

Circuit M

Loop	$k \times Q^{1.85}$	$= kQ^{1.85}$	$\times Q$	$= h$	
BC	12.0×25.4	$= 304$	$\times 45$	$= 13700$	
CH	3.0×10.0	$= 30$	$\times 15$	$= 450$	—14150←
BK	12.0×20.5	$= 246$	$\times 35$	$= 8610$	
KH	5.4×7.1	$= 38$	$\times 10$	$= 380$	— 8990
		618			5160

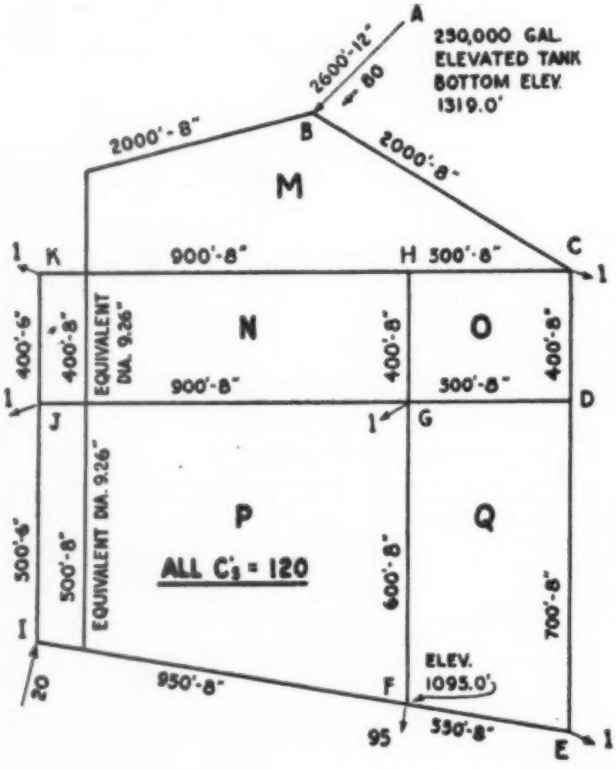


Fig. 10—Preliminary Sketch (For all pipes involved C is 120)

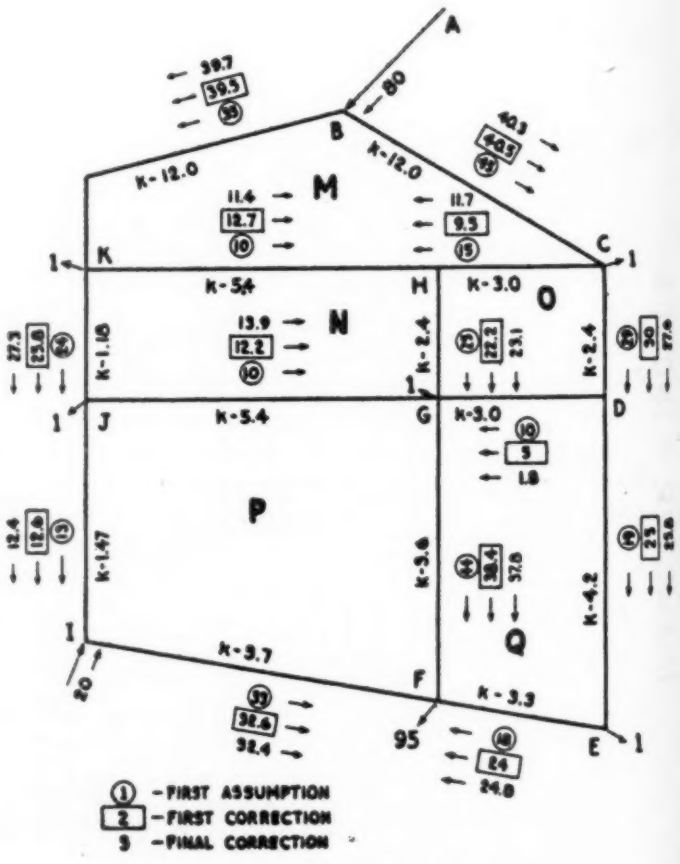


Fig. 11—Working Sketch

Diameter Pipe "A"	DIAMETER OF PIPE "B"															
	2	3	4	6	8	10	12	14	16	18	20	24	30	36	42	48
2	2.6	3.36	4.14	6.13	8.08											
3		3.90	4.64	6.35	8.25	10.18										
4			5.20	6.70	8.50	10.32	12.25									
6				7.80	9.26	10.92	12.70	14.60	16.40							
8					10.40	11.82	13.42	15.52	16.80	18.80	20.70	24.50	30.50	36.25		
10						13.10	14.42	16.00	17.60	19.45	21.25	24.85	30.60	36.50	42.40	
12							15.65	17.00	18.50	20.20	21.90	25.50	31.00	36.75	42.50	48.50
14								17.25	19.50	21.20	22.70	26.00	31.50	37.20	42.80	48.75
16									20.75	22.20	23.60	26.80	32.10	37.55	43.20	49.00
18										23.45	24.75	27.75	32.80	38.10	43.70	49.40
20											26.00	28.75	33.50	38.75	44.00	49.80
24												31.30	35.50	40.30	45.50	50.85
30													39.20	43.25	47.85	52.95
36														46.90	51.00	55.60
42															54.60	58.75
48																62.50

EXAMPLE: In parallel, a 6-inch and an 8-inch main are only equivalent to one pipe 9.26-inch in diameter.

Fig. 12—Equivalent Diameters

$$\text{Correction } \frac{5160}{1.85 \times 618} = 4.52$$

Circuit O

CD	2.4 × 17.5 =	42	× 29	=	1220		
DG	3.0 × 7.1 =	21	× 10	=	210	—	1430 ←
CH	3.0 × 10.0 =	30	× 15	=	450		
HG	2.4 × 15.4 =	37	× 25	=	925	—	1375
		130					55

$$\text{Correction } \frac{55}{1.85 \times 130} = 0.229$$

Circuit N

KH	5.4 × 7.1 =	38.0	× 10	=	380		
HG	2.4 × 15.4 =	37.0	× 25	=	925	—	1305 ←
KJ	1.18 × 14.9 =	17.6	× 24	=	422		
JG	5.4 × 7.1 =	38.0	× 10	=	380	—	802
		130.6					503

$$\text{Correction } \frac{503}{1.85 \times 130.6} = 2.08$$

Circuit Q

DE	4.2 × 12.2 =	51.2	× 19	=	970		
EF	3.3 × 11.6 =	38.2	× 18	=	687	—	1657
DG	3.0 × 7.1 =	21	× 10	=	210		
GF	3.6 × 25.0 =	90	× 44	=	3960	—	4170 ←
		200.4					2523

$$\text{Correction } \frac{2523}{1.85 \times 200.4} = 6.78$$

Circuit P

JG	5.4 × 7.1 =	38.0	× 10	=	380		
GF	3.6 × 25.0 =	90.0	× 44	=	3960	—	4340 ←
JI	1.47 × 8.9 =	13.1	× 13	=	170		
IF	5.7 × 19.5 =	111.0	× 33	=	3660	—	3830
		252.1					516

$$\text{Correction } \frac{510}{1.85 \times 252.1} = 1.09$$

Second Trial (Following First Correction)

Circuit M

Loop	$k \times Q^{1.85}$ =	$kQ^{1.85}$	× Q =	h		
BC	12.0 × 23.2 =	278.0	× 40.5 =	11260		
CH	3.0 × 6.8 =	20.4	× 9.5 =	194	—	11454 ←
BK	12.0 × 22.7 =	273.0	× 39.5 =	10800		
KH	5.4 × 8.7 =	47.0	× 12.7 =	597	—	11397
		618.4				57

$$\text{Correction } \frac{57}{1.85 \times 618.4} = 0.05$$

Circuit O

CD	2.4 × 18.0 =	43.2	× 30	=	1295		
DG	3.0 × 3.9 =	11.7	× 5	=	59	—	1354 ←
CH	3.0 × 6.8 =	20.4	× 9.5 =		194		
HG	2.4 × 14.0 =	33.6	× 22.2 =		745	—	939
		108.9					415

$$\text{Correction } \frac{415}{1.85 \times 108.9} = 2.19$$

Circuit N

KH	5.4 × 8.7 =	47.0	× 12.7 =		595		
HG	2.4 × 14.0 =	33.6	× 22.2 =		745	—	1340 ←
KJ	1.18 × 15.7 =	18.5	× 25.8 =		477		
JG	5.4 × 8.5 =	45.9	× 12.2 =		560	—	1037
		145.0					303

$$\text{Correction } \frac{303}{1.85 \times 145.0} = 1.23$$

Circuit Q

DE	4.2 × 15.4 =	64.7	× 25	=	1620		
EF	3.3 × 14.9 =	49.2	× 24	=	1180	—	2800
DG	3.0 × 3.9 =	11.7	× 5	=	59		
GF	3.6 × 22.2 =	80.0	× 38.4 =		3070	—	3129 ←
		205.6					329

$$\text{Correction } \frac{329}{1.85 \times 205.6} = 0.865$$

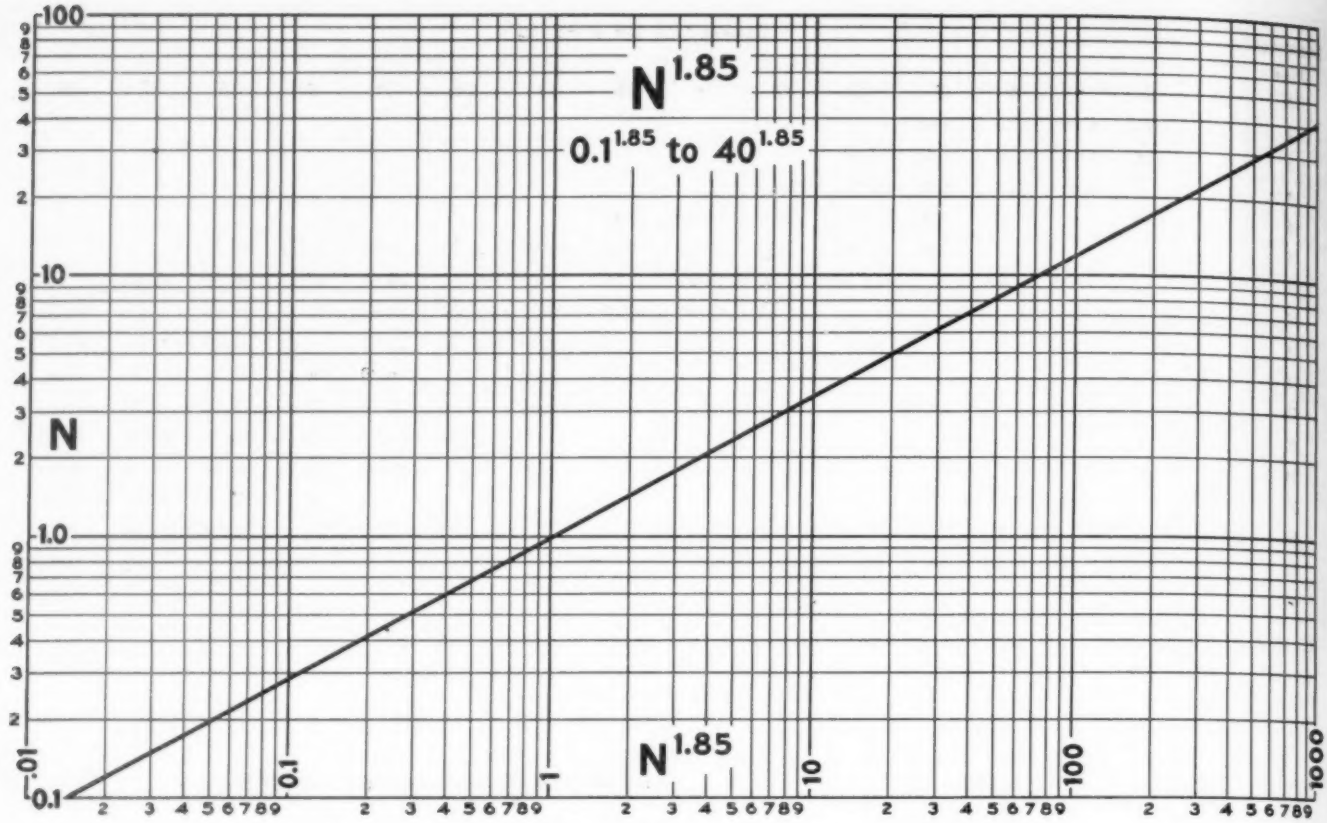


Fig. 13—The $N^{1.85}$ Power of Numbers

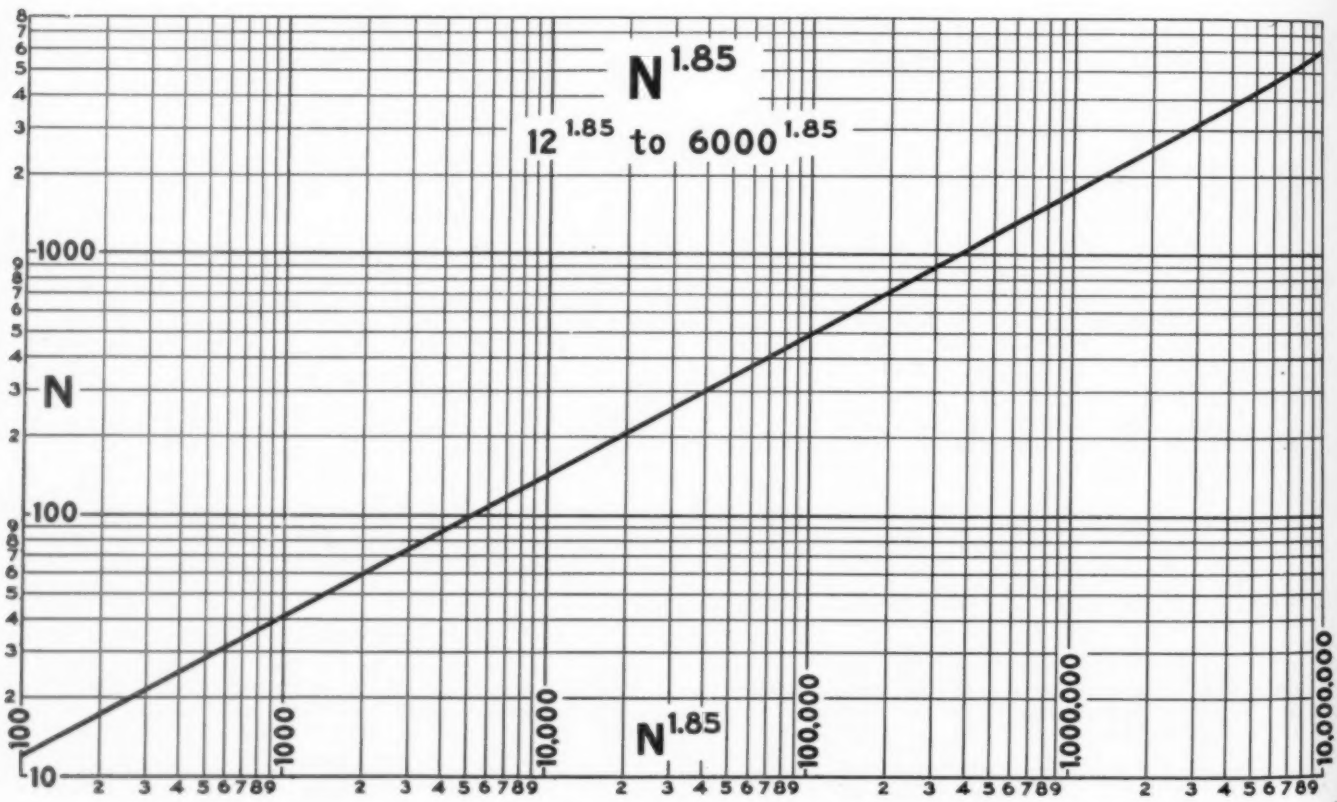


Fig. 14—The $N^{1.85}$ Power of Numbers

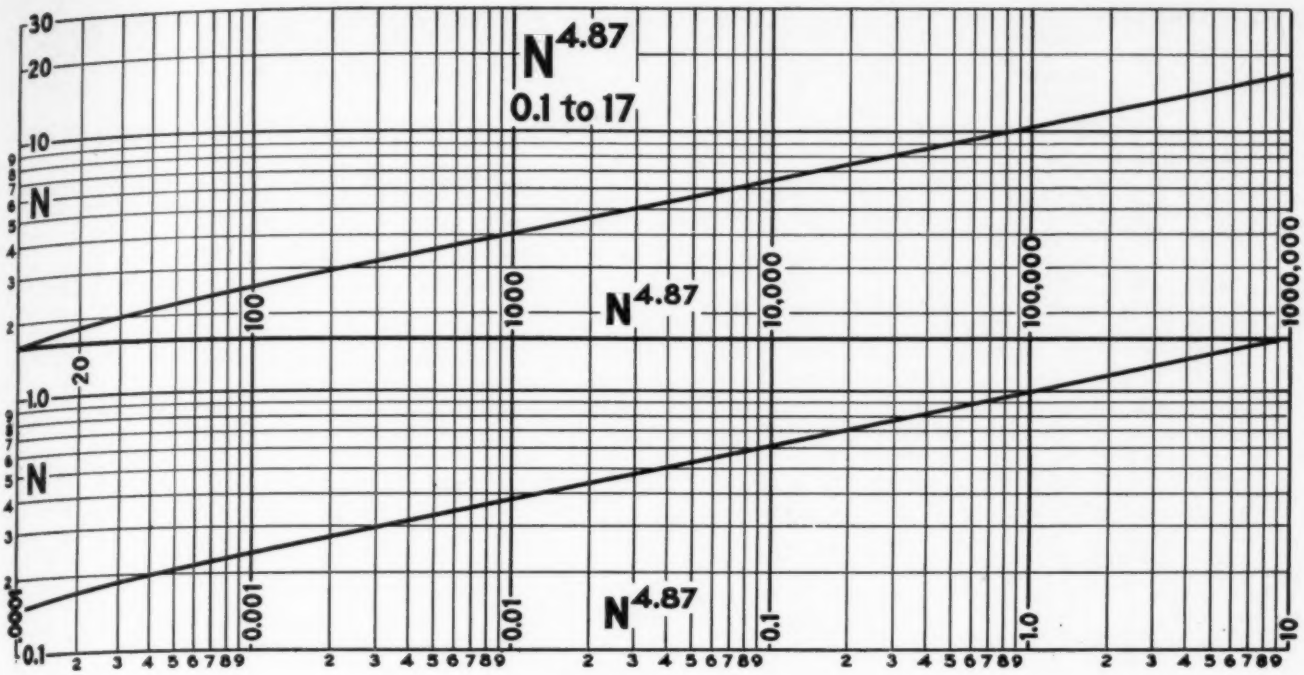


Fig. 15—The $N^{4.87}$ Power of Numbers

Circuit P

JG	5.4	× 8.5 =	49.5	× 12.2 =	560	
GF	3.6	× 22.2 =	80.0	× 38.4 =	3070	— 3630
JI	1.47	× 8.6 =	12.6	× 12.6 =	159	
IF	5.7	× 19.3 =	110.0	× 32.6 =	3590	— 3749 ←
			252.1			119

$$\text{Correction } \frac{119}{1.85 \times 252.1} = 0.255$$

Third Trial (Following Second Correction)

Circuit M

Loop	k	× $Q^{0.85}$	$kQ^{0.85}$	× Q	h	
BC	12.0	× 23.1 =	278	× 40.3 =	11200	
CH	3.0	× 8.1 =	24.3	× 11.7 =	284	—11484 ←
BK	12.0	× 22.8 =	274	× 39.7 =	10880	
KH	5.4	× 7.9 =	42.7	× 11.4 =	487	—11367
			619.0			117

$$\text{Correction } \frac{117}{185 \times 619} = 0.102$$

Circuit O

CD	2.4	× 16.7 =	40.0	× 27.6 =	1105	
DG	3.0	× 1.6 =	4.8	× 1.8 =	9	— 1114 ←
CH	3.0	× 8.1 =	24.3	× 11.7 =	284	
HG	2.4	× 14.4 =	24.6	× 23.1 =	797	— 1081
			93.7			33

$$\text{Correction } \frac{33}{1.85 \times 93.7} = 0.19$$

Circuit N

KH	5.4	× 7.9 =	42.7	× 11.4 =	487	
HG	2.4	× 14.4 =	24.6	× 23.1 =	797	— 1284 ←
KJ	1.18	× 16.6 =	19.6	× 27.3 =	535	
JG	5.4	× 9.4 =	50.7	× 13.9 =	705	— 1240
			135.5			44

$$\text{Correction } \frac{44}{1.85 \times 137.5} = 0.17$$

Circuit Q

DE	4.2	× 15.7 =	66.0	× 25.8 =	1768	
EF	3.3	× 15.2 =	50.2	× 24.8 =	1243	— 3011 ←
DG	3.0	× 1.6 =	4.8	× 1.8 =	9	
GF	3.6	× 21.8 =	78.4	× 37.8 =	2965	— 2974
			199.4			37

$$\text{Correction } \frac{37}{1.85 \times 199.4} = 0.10$$

Circuit P

JG	5.4	× 9.4 =	50.7	× 13.9 =	705	
GF	3.6	× 21.8 =	78.4	× 37.8 =	2965	— 3670
JI	1.47	× 8.5 =	12.5	× 12.4 =	155	
IF	5.7	× 19.2 =	109.5	× 32.4 =	3545	— 3700 ←
			251.1			30

$$\text{Correction } \frac{30}{1.85 \times 251.1} = 0.064$$

This design is corrected to less than two tenths of one per cent. For usual design a correction to anything less than one per cent is ample. As a matter of fact, k for KJ could just as well have been considered as 1.2 instead of 1.18 and k for JI as 1.5 instead of 1.47 without affecting the accuracy.

Proving the Method and Residual Pressure Determination

With a total flow of 2000 gpm the total friction loss from B to F will be—

Loop	h
BC	11200
CD	1105
DE	1768
EF	1243
	—15316
BK	10880
KJ	535
JI	155
IF	3545
	—15115
	30431

$$\frac{30431}{2} = 15{,}215 = \text{Average h from B to F}$$

By formula (6)—

$$S_t \text{ (B to F)} = \frac{15215}{100{,}000}\ (20)^{1.85}$$
$$= 0.152 \times 254^*$$
$$= 38.6'$$

(*From Chart, Fig. 14.)

Flow from A to B = 1600 gpm
From Flow Chart (Fig. 7) for this flow through a 12" main S = 7.0′ per 1000′, therefore S_t from A to B is—

$2.6 \times 7.0 = 18.2'$, then
S_t (A to F) = 18.2 + 38.6 = 56.8′
Therefore, at 2000 gpm. total flow (1900 gpm. at point F) the friction loss amounts to 56.8 ft.

Elevation—bottom of tank	1319.0′
Elevation—point F	1095.0′
Total available head (H)	224.0′
Friction loss (A to F)	56.8′
Residual flow head at F	167.2′

Residual pressure (P) at F $= \frac{167.2}{2.31} = 72.4$ psi with Q = 1900 gpm.

With a flow of 2700 gpm at F, what will be the residual pressure?

S varies as the 1.85 power of Q.

$$(13)\text{—}S_2 = S_1 \left[\frac{Q_2}{Q_1}\right]^{1.85}$$

$$\text{By (13)—}S_2 = 56.8 \left[\frac{2700}{1900}\right]^{1.85}$$
$$= 56.8\ (1.42)^{1.85}$$
$$= 56.8 \times 1.91\dagger$$
$$= 108.5'$$

(†From Chart, Fig. 13.)

Total available head	224.0′
S_t from A to F with Q = 2700	108.5′
Residual (flow) head—H	115.5′

Residual pressure at F with Q = 2700 $= \frac{115.5}{2.31} = 49.7$ psi.

Considering 20 psi as the lowest residual (flow) pressure permissible for good fire protection, what is the maximum safe flow possible, at this pressure, at point F?

20 psi = 20 × 2.31 = 46.2′

Total available head	224.0′
20 psi	46.2′
Total available head for friction loss	177.8′

Q varies as the 0.54 power of S (see Figure 16)

Formula (14)—

$$Q_2 = Q_1 \left[\frac{S_2}{S_1}\right]^{0.54}$$

$$\text{By (14)—}Q_2 = 1900 \left[\frac{177.8}{56.8}\right]^{0.54}$$
$$= 1900\ (3.13)^{0.54}$$
$$= 1900 \times 1.855\ddagger$$
$$= 3520 \text{ gpm.} = \text{maximum flow with a residual pressure of 20 psi. at F.}$$

(‡From Chart, Fig. 16.)

These are safe figures, because this method presupposes that the domestic take-offs of 1% at points C, E, G, J and K will also increase correspondingly; however, this will probably not be the case, hence the calculated residual pressures and flows will be slightly more than indicated, but the per cent of domestic take-off is so small, it is not necessary to lose the time required to balance the flows all over again for this increase of flow at F.

The accuracy of the above calculations in this particular case depends somewhat upon the characteristics of the pump, that is,

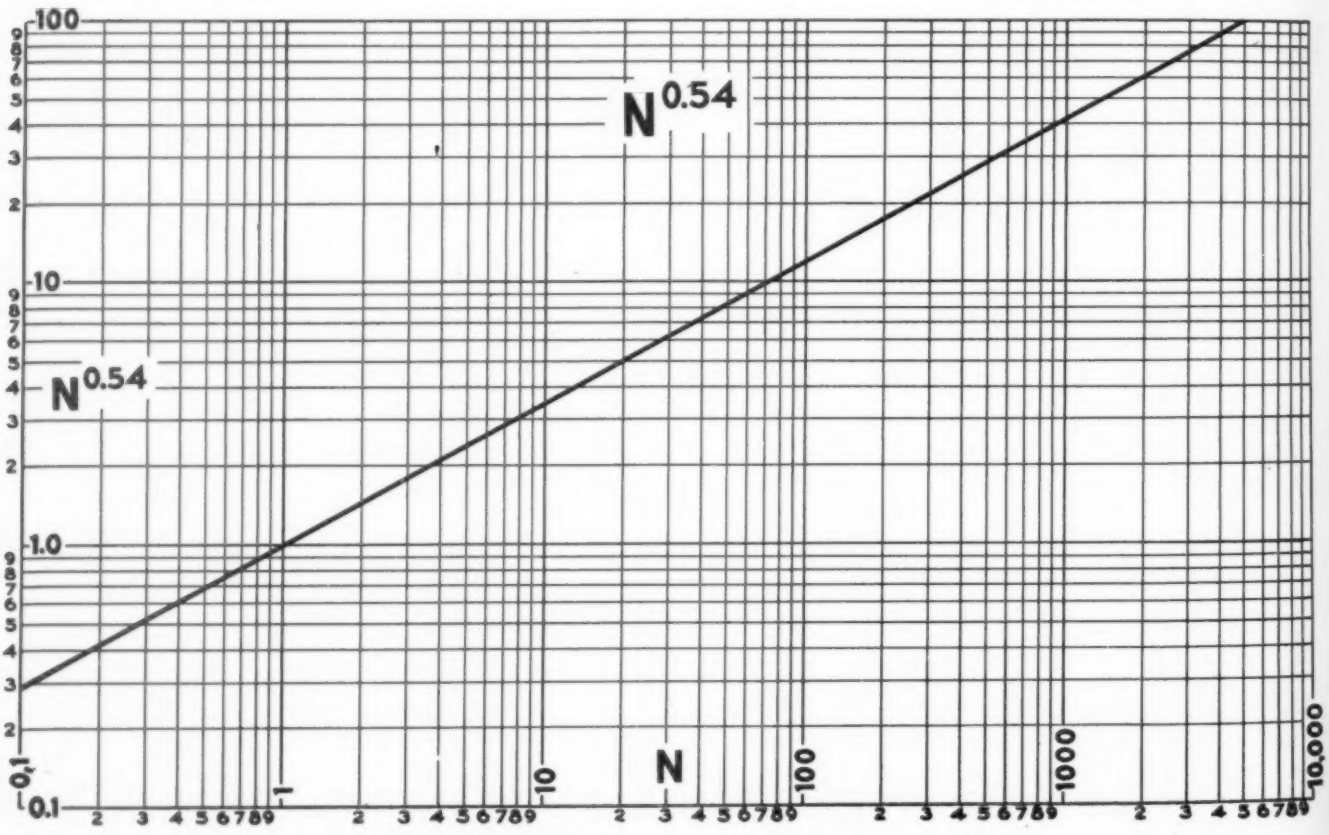


Fig. 16—The $N^{0.54}$ Power of Numbers.

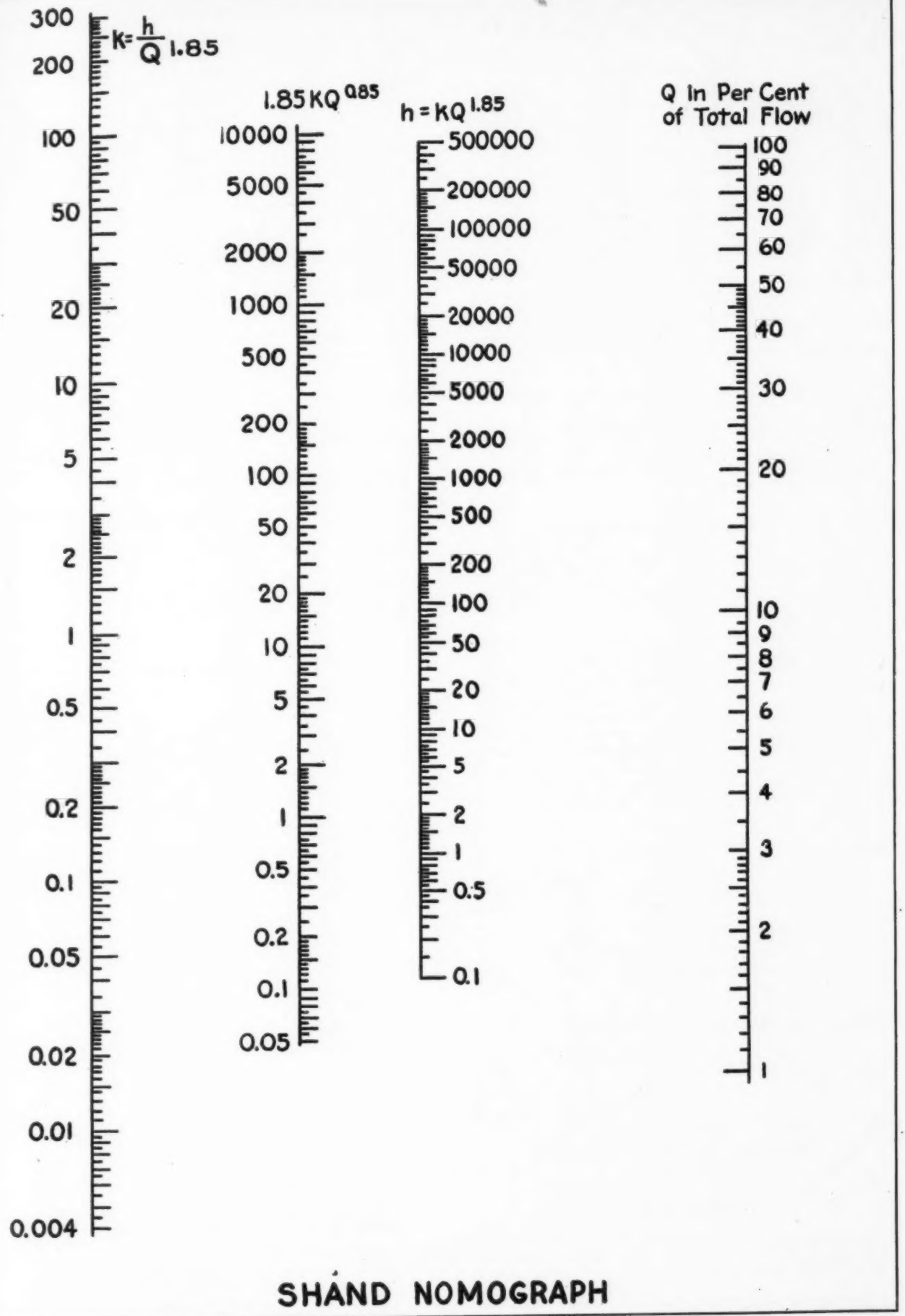


Fig. 17—Shand's Nomograph for Use in Applying the Hardy Cross Method

VALUES OF "R" FOR 1,000 FT. OF PIPE BASED ON HAZEN AND WILLIAMS FORMULA

Head Loss in Ft.: $S = r \times Q^{1.85}$ per 1,000 ft. (Q in M.G.D.)

d—Inches	c = 70	c = 80	c = 90	c = 100	c = 110	c = 120	c = 130	c = 140
4	860.69	672.31	540.67	444.91	373.00	317.53	273.83	238.76
6	119.44	93.30	75.03	61.74	51.76	44.06	38.00	33.13
8	29.42	22.98	18.48	15.21	12.75	10.85	9.36	8.16
10	9.93	7.75	6.24	5.13	4.30	3.66	3.16	2.75
12	4.08	3.19	2.57	2.11	1.77	1.51	1.30	1.13
14	1.925	1.504	1.209	0.995	0.834	0.710	0.612	0.534
16	1.007	0.787	0.633	0.521	0.437	0.372	0.320	0.279
18	0.567	0.443	0.356	0.293	0.246	0.209	0.180	0.157
20	0.3390	0.2648	0.2130	0.1753	0.1469	0.1251	0.1079	0.0941
24	0.1396	0.1091	0.0877	0.0722	0.0605	0.0515	0.0444	0.0378
30	0.0471	0.0368	0.0296	0.0244	0.0204	0.0174	0.0150	0.0151
36	0.01939	0.01514	0.01218	0.01002	0.00840	0.00715	0.00617	0.00528
42	0.00915	0.00715	0.00575	0.00473	0.00397	0.00338	0.00291	0.00254
48	0.004774	0.003729	0.002999	0.002468	0.002057	0.001761	0.001519	0.001324
60	0.001611	0.001258	0.001012	0.000833	0.000698	0.000594	0.000513	0.000447
66	0.001013	0.000791	0.000636	0.000524	0.000439	0.000374	0.000322	0.000281

Fig. 18—Values of "R" for 100 ft. of Pipe (Hazen and Williams Formula).

its ability to assume its proportion of the increased flows; however, with booster pumps having a pressure head on their suction, it is reasonable to suppose that the drop in discharge heads, resulting from increased flows, will result in a proportionate increase in discharge from the pump. For extreme accuracy, a head-capacity curve of the pump in question should be used in conjunction with the design.

The Shand Nomograph

With the use of the Shand Nomograph* (Fig. 17) many calculations are obviated, thereby facilitating exceedingly the work of designing or evaluating a large system. The use of the nomograph is very simple; however, the various values are slightly rearranged.

The values of k and Q may be considered the knowns and the values of $1.85kQ^{0.85}$ and h the unknowns. Therefore, knowing k and Q, a straight edge, a transparent triangle or a transparent plastic ruler may be laid across the nomograph even with k and Q, and the values of $1.85kQ^{0.85}$ and h may be read directly where the edge of the ruler crosses these respective scales. The per cent of correction is equal to the difference of the h values of each loop divided by the sum of the values of $1.85kQ^{0.85}$.

For example, consider Fig. 5 again and the calculations made for it. The values are arranged as shown, the knowns on the left and the unknowns read from the nomograph and placed on the right.

First Trial

Loop	*k*	*Q*	$1.85kQ^{0.85}$	*h*
ABCD	18	25	525	7000
AD	6	75	440	18000←
			965	11000

$$\text{Correction } \frac{11000}{965} = 11.4$$

Second Trial (Following First Correction)

Loop	*k*	*Q*	$1.85kQ^{0.85}$	*h*
ABCD	18	36	700	14000←
AD	6	64	375	13400
			1075	600

$$\text{Correction } \frac{600}{1075} = 0.56\text{—No correction}$$

Rates in M.G.D.

For those who prefer to value flows in millions of gallons per day, Fig. 18 may be used. This table is especially useful when dealing with large mains and large rates of flow. The use of this table in balancing flows is identical with that of Fig. 2, with the exception that a different formula is used for calculating the total friction loss, and a slight difference in nomenclature.

Nomenclature and Formulas

Q_x = million gallons per day expressed as 1, 1.5, 2.6, 25, 150, etc.

(15)— $S = r\,Q_x^{1.85}$

(16)— $r = \dfrac{S}{Q_x^{1.85}}$

(17)— $S_t = h_f\ (.01\ \text{M.G.D.})^{1.85}$

(18)— $S_t = r\,Q_x^{1.85}$

(19)— $a^{1.85} = a \times a^{0.85}$

(Courtesy Burns and McDonnell Engineering Co.)

Examples of Use

Consider Figs. 4 and 5. From Fig. 18, it will be found that r = 10.85 for 8" pipe with C = 120. Therefore, r for loop ABCD = 3 × 10.85 = 32.55, and for loop AD it is 1 × 10.85 = 10.85. Using the same values in the first trial previously used when calculated on the Q_m basis, the calculations are as follows:

First Trial

Loop	$r \times Q_x^{0.85} = rQ_x^{0.85} \times Q = h_t$			
ABCD	32.55 × 15.4 =	500 × 25 =	12500	
AD	10.85 × 39.1 =	424 × 75 =	31800←	
		924	19300	

$$\text{Correction } \frac{19300}{1.85 \times 924} = \frac{19300}{1709.4} = 11.3$$

Second Trial

ABCD	32.55 × 21.0 =	684 × 36 =	24600←
AD	10.85 × 34.2 =	371 × 64 =	23800
		1055	800

$$\text{Correction } \frac{800}{1.85 \times 1055} = \frac{800}{1950} = 0.41$$

$$\text{Average } h_t = \frac{24600 + 23800}{2} = 24200$$

For a flow of 1 million gallons per day ($Q_x = 1$), the total friction from A to D in either loop will equal,

By formula (17)—

$$S_t = 24200\ (.01)^{1.85}$$
$$= 24200 \times .000195$$
$$= 4.71 \text{ feet}$$

This value agrees with the value previously obtained for

*Developed by H. Shand, Engineer, Greater Winnipeg Water District, Winnipeg, Canada.

$Q_m = 695$ (one million gallons per day) shown earlier when considering Figs. 4 and 5.

For a total flow of two million gallons per day ($Q_x = 2$), total friction loss (S_t) by formula 17 will equal—

$$S_t = 24{,}200\ (.02)^{1.85}$$
$$= 24{,}200 \times .00072$$
$$= 17.42 \text{ feet}$$

Considering Figs. 4 and 5,
36% of 2 = .72 M.G.D.
64% of 2 = 1.28 M.G.D.
For loop ABCD (formula 18)

$$S_t = 32.55 \times (.72)^{1.85}$$
$$= 32.55 \times .545$$
$$= 17.73 \text{ feet}$$

This value agrees with the value obtained with formula 17 immediately preceding.

Formulas 15, 17 and 18 are easily used in connection with Fig. 3, for all numbers from 1 to 100. For instance $(25)^{1.85}$ equals 25 multiplied by $(25)^{0.85}$. From Fig. 3 we find that $(25)^{0.85}$ equals 15.4. Therefore, by (19)

$$(25)^{1.85} = 25 \times 15.4$$
$$= 358$$

Again considering Figs. 4 and 5, S_t from A to D (loop AD) equals, for $Q_x = 2$, $S_t = 10.85 \times 1.28$ (64% of 2) $\times (1.28)^{0.85}$

From Fig. 3, by interpolation $(1.28)^{0.85}$ equals 1.224 approximately, and

$$= 10.85 \times 1.28 \times 1.224$$
$$= 17 \text{ feet}$$

This value agrees closely enough with the two values preceding.

In conclusion it might be stated that with the use of log log and an H & W slide rule all calculations involving exponential formulae are immensely facilitated.

References

(1) Hardy Cross, "Analysis of Flow in Networks of Conduits or Conductors," Univ. of Ill., Exp. Sta., Bull. 286, 1936.

(2) W. D. Hurst and N. S. Bubbis, "Application of the Hardy Cross Method to the Analysis of a Large Distribution System," Jour. AWWA. Vol. 34, No. 2, 1942.

(3) H. E. Babbitt and J. J. Doland, "Water Supply Engineering," 1939—a text 1939.

(4) H. G. Payrow, "Sanitary Engineering"—a text 1941.

(5) Burns and McDonnell Engineering Co., "Hydraulic Analysis for Water Distribution Mains, 1942."

INCLINED DIAGONAL PIPE RUNS
CALCULATING PIPE LENGTHS

By CHARLES FRICK

Water works men may find the following formulas interesting and helpful in figuring lengths of pipe and tie rods on inclined diagonal runs.

The formulas are also useful in finding the approximate angle of fitting, theta (Θ), required (when bell and spigot pipe and fittings are used) when the dimensions in three planes have been decided upon.

The evolution of the formulas (see illustration) are also given in case the principle of revolution to a vertical plane may have further advantages in similar problems.

The subtraction of the center to end of spigot and center to back of bell taken from D gives the true length of pipe required.

Sketch Explanatory of Formulas for Lengths of Pipe for Diagonal Runs and Angle of Fittings

A.—When measurements in three planes are known, then

$$D = \sqrt{A^2 + B^2 + C^2} \qquad \text{Formula I}$$

$$L\ (\Theta)^{-\tan} = \frac{\sqrt{A^2 + B^2}}{C} \qquad \text{Formula II}$$

Example: Let A = 5′6″, B = 3′0″, C = 14′9″
Find (Θ) and length of pipe required on 8″ line.

$$D = \sqrt{(5.5)^2 + (3)^2 + (14.75)^2}$$
$$= \sqrt{30.25 + 9 + 217.56} = 16.025' \text{ say } 16'0''$$

$$L\ (\Theta)^{-\tan} = \frac{\sqrt{(5.5)^2 + (3)^2}}{14.75} = \frac{\sqrt{30.25 + 9}}{14.75}$$

$$= \frac{\sqrt{39.25}}{14.75} = \frac{6.265}{14.75} = 0.42474$$

L (Θ) = 23° + and a one-sixteenth curve may be used.
Length of pipe = D — (C to E of S. + C to B of B.)
= 16′0″ — (2′1″+) = 13′11″—

B.—When measurements in two planes are known and angle f fitting (Θ) decided upon, then

$$D = \sqrt{A^2 + B^2} \times \text{Csc } (\Theta) \qquad \text{Formula III}$$

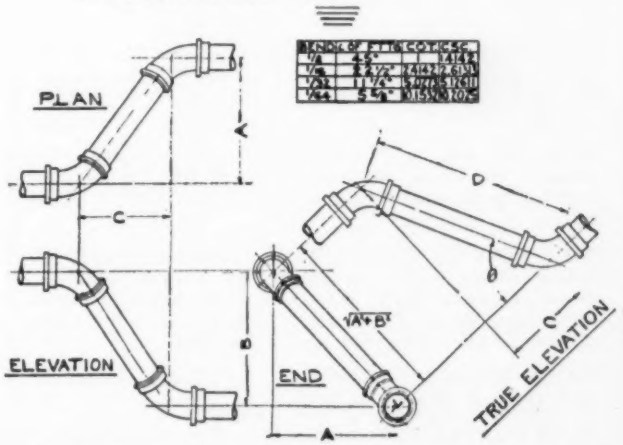
$$C = \sqrt{A^2 + B^2} \times \text{Cot } (\Theta) \qquad \text{Formula IV}$$

Example: Let A = 8′0″, B = 9′6″, (Θ) = 45°
Find—C and length of pipe required on 12″ line.

$$D = \sqrt{(8)^2 + (9.5)^2} \times \text{Csc } 45°$$
$$= \sqrt{64 + 90.25} \times 1.4142$$
$$= 17.56' = 17'6\tfrac{3}{4}''$$

Length of pipe = D — (C to E of S. + C to B of B.)
= 17′6¾″ — (2′1⅞″) = 15′4⅞″

$$C = \sqrt{(8)^2 + (9.5)^2} \times \text{Cot } 45°$$
$$= \sqrt{64} = 90.25 \times 1$$
$$= 12.42 \times 1 = 12.42' = 12'5''$$



Sketch Explanatory of Formulas for Lengths of Pipe for Diagonal Runs and Angle of Fittings

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Executive Offices: 22 E. 40th Street, New York, N. Y.

Offices in all large Cities

●

TRANSITE PRESSURE PIPE — TRANSITE SEWER PIPE

TRANSITE PRESSURE PIPE . . . *a brief discussion of how this asbestos-cement pipe can help you provide more efficient water service at lower cost—*

A SUMMARY OF TRANSITE PIPE'S OUTSTANDING CHARACTERISTICS

●

MADE OF ASBESTOS AND CEMENT — Transite Pipe is built up under tremendous pressure on a polished steel mandrel to form a homogeneous structure of great strength and uniformity.

RESISTANT TO VIBRATION—By virtue of its flexible joints, Transite Pipe is resistant to the shock and vibration of traffic; authoritative reports from abroad indicate the ability of flexibly connected asbestos-cement pipe to withstand indirect bomb shock with little or no effect on the performance of the line. Simplex Couplings divide the line into a series of flexible links which relieve the line of high flexural stresses and which have been found to localize damage in the case of direct hits.

HIGH CARRYING CAPACITY — Because of its smooth interior, Transite Pipe provides an unusually high flow coefficient, C=140.

CANNOT TUBERCULATE — Because it is nonmetallic, Transite Pipe can never rust or tuberculate. As a result, delivery capacity can never be reduced by this internal corrosion — expensive cleaning to remove tubercules is never required.

HIGHLY RESISTANT TO CORROSION — One of the important advantages of Transite's asbestos-cement composition and unusually low free-lime content is high resistance to corrosion — inside, outside and all the way through. Thousands of installations attest to Transite's durability in all kinds of soils.

TIGHT FLEXIBLE JOINTS—Composed of a Transite sleeve and two rubber rings, the Simplex Couplings used in Transite lines provide unusually tight, yet flexible joints.

WORKING PRESSURES—Transite Pipe is made in pressure classes of 50, 100, 150 and 200 for normal working pressures of 50, 100, 150 and 200 lbs. per sq. in.

EACH LENGTH RIGIDLY TESTED—Every length of Transite Pipe is individually tested to four times its specified rating in a hydrostatic test machine. In those sizes where flexural strength is important, each length of pipe is also subjected to a beam test.

SIZES—Transite Pipe is made in a wide range of sizes from 2 inch to 36 inch.

EASILY INSTALLED — Transite Pipe is furnished in long, 13-ft. lengths. Relatively light in weight, they are easily handled and installed. Simplex Couplings are assembled quickly and easily, even in wet trenches — a simple hydraulic coupling puller is the only tool required.

IN SELECTING a water pipe — whether for an extension or replacement of existing lines or the installation of a complete new system—careful consideration should be given to the basic factors contributing to the economic life of the pipe. For example:

DELIVERY CAPACITY . . .

Waterworks engineers generally agree that a water main, even though it remain structurally intact, may completely outlive its economic usefulness over a period of time. This point is reached when the pipe will no longer carry, economically, a sufficient volume of water to meet demand. Such a condition may arise from characteristics inherent in the pipe itself, from increased demand or from a combination of these two causes. Thus, in designing water systems, the engineer is faced with the responsibility of anticipating and solving these problems.

To compensate for expected reductions in carrying capacity, specifications often call for larger sizes of pipe than would otherwise be necessary. However, there is another, more fundamentally sound solution. In J-M Tran-

One of the hundreds of American Municipalities, where Transite Pipe is providing unusually efficient, economical water service. Transite's speed of assembly reduces the time trenches must be open—minimizes traffic congestion and inconvenience to business.

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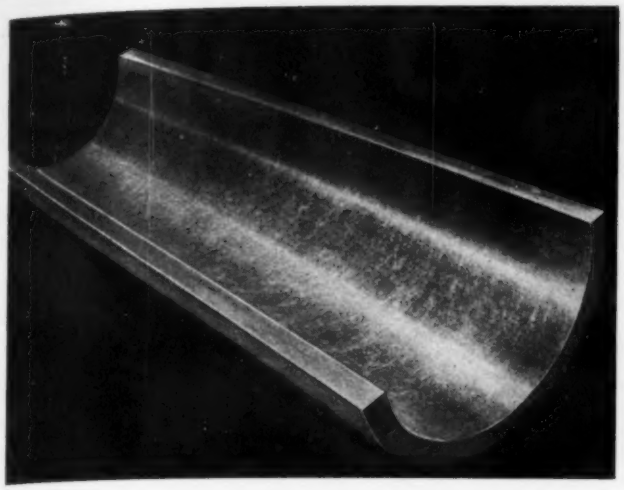


Because it is immune to tuberculation, wherever used, Transite Pipe assures an abundant supply of water through the years with low pumping costs.

Over 62,000 feet of 10-inch to 30-inch Transite Pipe were used on this water collection and transmission system. Because of its light weight and speed of assembly, the pipe was laid as fast as the trench was opened.

site Pipe, engineers find basic advantages that permit them to specify the most economical pipe sizes with full assurance that delivery capacity will not be reduced by tuberculation, the internal corrosion which, even when present in relatively small degree, greatly reduces the carrying capacity of ordinary pipe.

Transite Pipe is an asbestos-cement product. During manufacture, it is built up on a polished steel mandrel that imparts unusual smoothness to the interior wall. Its flow coefficient is conservatively established at C = 140. This means that Transite water lines start with an exceptionally high carrying capacity.

Transite's freedom from tuberculation means that pumping costs stay low, for pressures need not be increased to compensate for a steadily decreasing flow coefficient and resulting loss of head in the line. Not only does this advantage provide worthwhile operating economies, but in many cases it also permits the use of smaller diameter pipe with resultant savings in all the numerous items that go to make up the original cost of completed water lines.

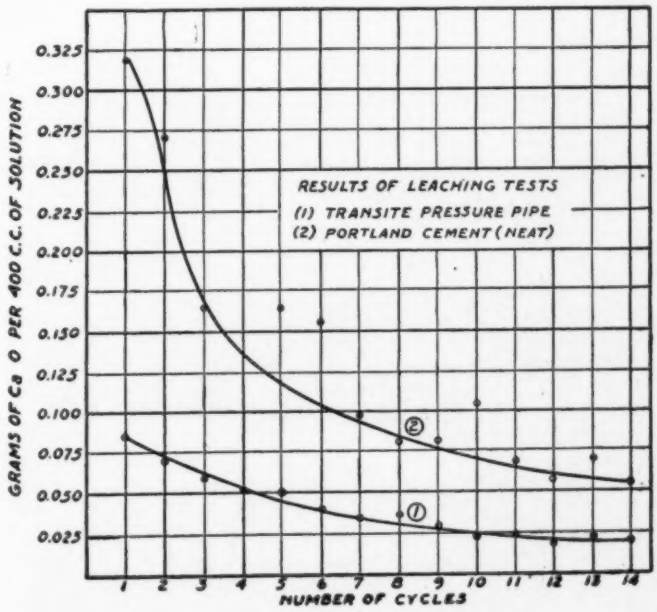
SOIL CORROSION . . .

Broadly speaking, most soil corrosion engineers agree that there are two principal forms of soil corrosion — chemical and electro-chemical.

Chemical corrosion is caused by the direct, corrosive action of acids and salts encountered in the soil. Transite Pipe, due to a special process of manufacture and treatment, is virtually inert to concentration of acids and salts ordinarily found in soils. Free lime which might generally be expected in cement products, has been largely converted to insoluble silicates due to the method of manufacture. A comparison of the two curves in the diagram below shows the high degree of insolubility of Johns-Manville Transite Pipe. It is for this reason that Transite is so highly resistant to all forms of chemical corrosion.

Electro-chemical corrosion is caused by the electrolytic action between ordinary pipe and materials in the soil. This action is similar to that of a simple electric cell. In this case, the materials in the soil represent the positive pole; the soil moisture, the electrolyte, and the pipe wall serves as the negative pole. The current generated passes from the pipe to the positive pole and causes a gradual disintegration of the pipe structure.

With Transite, however, this condition can never



The chart above represents a series of leaching cycles for both pulverized Transite Pipe and neat cement. The small amount of free lime extracted from Transite indicates that for all practical purposes it may be considered insoluble—one of the major factors responsible for its unusual resistance to soil corrosion.

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occur, because being non-metallic, Transite is a non-conductor—therefore absolutely free from electrical corrosion. Furthermore, this asbestos-cement pipe is immune to electrolysis caused by stray electric current from high voltage lines, streets, railways, etc.

The successful performance of Transite Pipe in all kinds of soil and under many varying climatic conditions provides practical proof of its high resistance to corrosion—inside, outside and all the way through.

JOINT LEAKAGE . . .

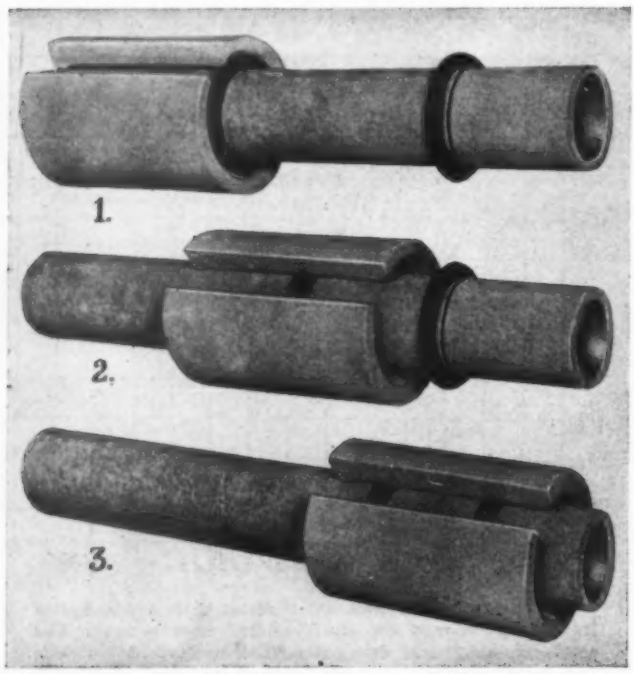
Numerous surveys have shown that leaky joints are responsible for a considerable portion of total water losses from underground mains. Generally recognized by waterworks men as a serious problem, joint leakage not only results in a direct waste of water but, by washing away supporting soil, frequently causes pipe to fracture under traffic and earth loads.

Much of this trouble is caused by the fact that the ordinary rigid joint, even though perfectly made by skilled workmen, may open up when subjected to vibration or settlement after the line is in service.

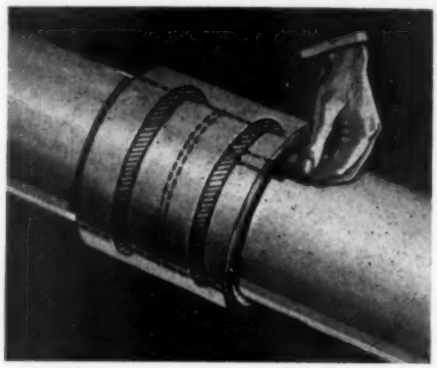
Such potential losses are minimized with a flexible joint. And that is the principle upon which the Simplex Coupling, employed in assembling Transite Pipe, was designed. Consisting of a Transite sleeve and two rubber rings, it forms a tight joint that stays tight in service. Its flexibility compensates for vibration and for vertical, longitudinal and lateral movements to which the pipe may be subjected underground. Depending upon the size of the pipe, a deflection of as much as 5° is possible at each joint.

From a practical standpoint, the less skill required in assembly, the less the danger of defective joints in the field. The dependability of the Simplex Coupling is due primarily to these distinctive features:

1. It is actually a pre-fabricated, "packaged" joint. The ends of each pipe and the inside of each coupling are machined to specific dimensions. The rubber rings are precision-made and subjected to rigid inspection before shipment. Joints are assembled cold—no pouring, caulking or heating equipment is needed. A simple hydraulic coupling puller, loaned by Johns-Manville without charge, is the only tool required for assembly.



Simplex Couplings Assembly (1) at start of operation (2) sleeve pulled over one ring, (3) final position, sleeve centered over joint.



With Simplex Couplings tightness of the joint can be determined from the outside as soon as the pipe is laid. A thin steel blade, slipped under the lip of the sleeve, checks the position of the rubber ring. If the position is right, the joint is tight.

2. The effectiveness of the joint does not depend on the individual skill or training of the workmen. So simple is the operation that perfect Simplex joints can be made quickly and economically even by unskilled crews.

Made of Permanent Materials. The Transite sleeve, like the pipe itself, is made of asbestos and cement and has the same high degree of resistance to all forms of corrosion. The rings, made of the highest quality rubber, are carefully cured and specially compounded with anti-oxidents and properly graded non-hygroscopic fillers to assure permanence in water service.

INSTALLATION . . .

One of the major factors contributing to initial cost of a pipe line is the time and equipment required for installation.

Transite Pressure Pipe offers primary advantages that help speed up installation and cut costs. The long, 13-ft. lengths are relatively light in weight. Two or three men can easily lower 8 inch pipe into the trench by hand. In fact all but the very largest sizes can be handled without the use of mechanical equipment.

Simplex Couplings are assembled cold just as they are received from the factory. Wet trenches present no problem for no heating or caulking equipment is required. And the complete assembly is completed in much less time than required by ordinary types of joints.

WRITE FOR COMPLETE DETAILS

A detailed discussion of the economic factors contributing to efficient, low-cost water lines is given in the Transite Pressure Pipe Brochure, TR-11A. The 76-page "J-M Pipe Installation Manual," D. S. 332, outlines effective methods of installing water lines and includes much more data on Transite Pipe and the Simplex Coupling than was possible to include on these pages. For detailed data on making repairs to transite lines damaged by enemy action the booklet, "Transite Pipe—Repair of War Damage" will be found helpful. It is profusely illustrated and contains numerous diagrams and data pertinent to the maintenance of flow in the event of hostilities. For your free copy of these three books, write to Johns-Manville, 22 East 40th Street, New York, N. Y.

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IN YOUR SEWAGE DISPOSAL SYSTEMS - - -

Transite Sewer Pipe offers fundamental advantages that help reduce the cost of sewer line construction, maintenance and operation.

TRANSITE PRESSURE SEWER PIPE

Pressure Sewer Lines are very similar in operation to water lines and must meet the same general service requirements. In addition, the pipe must be highly resistant to the corrosive action of the sewage. Transite Pressure Sewer Pipe, which is made of the same durable asbestos-cement composition as Transite Water Pipe, described on the preceding pages, meets all these requirements and provides highly satisfactory service in systems of this type.

TRANSITE GRAVITY SEWER PIPE

Gravity Sewer Lines offer a number of specialized problems which Transite Gravity Sewer Pipe meets eminently well. For example:

INFILTRATION—

It has been authoritatively estimated that as much as 25% of the contents of the average sewer is ordinary ground water that enters the system by infiltration through the joints. And it costs practically as much to treat this water at the disposal plant as it does to treat sewage itself. Furthermore, in many cases, engineers must allow for this huge quantity of water by specifying a larger diameter pipe than would otherwise be necessary.

With Transite Sewer Pipe, however, the infiltration of ground water presents no serious problem. Transite's long 13-ft. lengths cut down the number of joints in the line, thus reducing the danger of infiltration right at the start. The poured sleeve joints employed in Transite lines are unusually tight and stay tight in service. The jointing compound is the highest quality, unfilled asphalt which, when set, provides a strong, flexible joint that is highly resistant to cracking or shrinkage. As a result, Transite Sewer Pipe lines have considerably less infiltration than that allowed by most specifications.

Transite, the corrosion-resistant, asbestos-cement sewer pipe, answers every requirement of efficient sewerage service. Its long 13-ft. lengths make laying to exact grades a quicker and more accurate job. And the tight joints employed minimize infiltration.

CARRYING CAPACITY

One of the most important factors in any sewer line is carrying capacity. All other things being equal, the relative carrying capacity of two or more types of pipe is best indicated by their flow coefficient. If, for example, the inside of the pipe is rough and uneven, the flow velocity is low and carrying capacity is greatly reduced. A smooth pipe, however, has a high flow velocity and a correspondingly high carrying capacity.

Transite Sewer Pipe has an unusually smooth interior surface, its conservative friction coefficient when installed at the usual sewer pipe grade is N=.010. This high carrying capacity results in savings that can be taken in one of two ways. Flatter grades may be employed during installation — reducing the depth of the trench and making installation a faster, more economical job. Or, when the usual sewer pipe grade is maintained and deep trenches present no problem, Transite's high flow velocity often makes it possible to use a smaller diameter pipe without reducing the desired carrying capacity of the system.

OTHER CONSIDERATIONS

Resistance to corrosion, structural strength and ease of installation are, of course, other important considerations in the selection of sewer pipe.

Because of its asbestos-cement composition and its unusually low free lime content, Transite Sewer Pipe is highly resistant to the corrosive action of all types of domestic sewage and most industrial wastes—inside, outside and all the way through.

Transite Sewer Pipe is furnished in sizes from 4" to 36" in Class I, from 10" to 36" in Classes II and III and from 18" to 36" in Class IV. Each class of pipe is made to a specific crushing strength, thereby providing for the selection of the most economical combination of classes of pipe to meet the specific strength requirements of the line.

The long 13-ft. sections in which Transite is furnished eliminates many of the difficulties in installation common to ordinary short length sewer pipe. Relatively light in weight, these long lengths cut down handling costs. More footage may be carried per truck load to the trench and fewer men are needed to install the pipe. These long lengths also reduce the number of joints that must be made and thus save considerable time and labor. In addition, long lengths greatly facilitate laying the pipe to an accurate grade.

It will pay you to get further details about this modern sewer pipe. Brochure TR-21A presents them in brief, quickly read form. The "Transite Sewer Pipe Installation Manual" D.S. 342 gives valuable information and tabular data pertinent to installation problems. Write for these from Johns-Manville, 22 East 40th Street, New York, N. Y.

JOHNS-MANVILLE JM PRODUCTS

PITTSBURGH-DES MOINES STEEL CO.

Tanks—Plate Fabrication—Structural Steel

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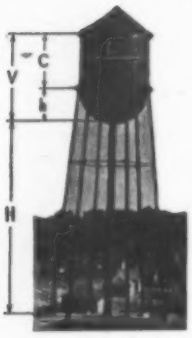
1223 PRAETORIAN BLDG., DALLAS, TEX. . . . 625 RIALTO BLDG., SAN FRANCISCO, CALIF.

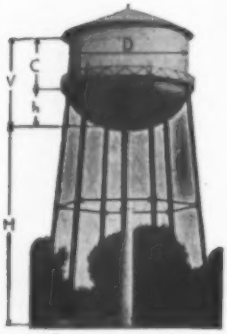
In these tables we have compiled—in compact but complete form—data on steel reservoirs and on the various types of elevated steel tanks. For information as to the application of these various types of tanks, for designs, for specifications, or for estimates—write our nearest office.

Table I—Pittsburgh-Des Moines Standard Hemispherical Bottom Elevated Tanks



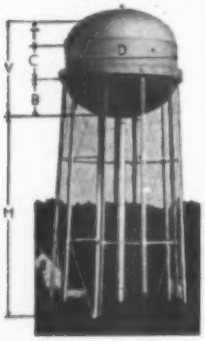
Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity											
				ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
5,000	9	10 0	11 3	11 3	18 9	31 9	38 3	51 9	58 9	72 9	79 9	93 9	100 9	.....	.....
10,000	13	5 11	11 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
15,000	13	10 11	16 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
20,000	13	15 11	21 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
25,000	15	14 7	19 11	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....
30,000	15	18 5	23 9	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....
40,000	17	18 5	25 1	46 8	.....	.....	75 0	.....	96 3	100 0	.....	125 0	.....	.....	.....
50,000	19	17 7	25 7	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
60,000	19	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
75,000	21	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
100,000	24	22 6	31 0	.....	50 0	63 1	75 0	79 7	91 6	100 0	113 1	116 6	125 0	141 6	153 4
150,000	28	24 2	34 7	46 6	54 10	63 2	75 0	83 4	91 8	100 0	111 10	120 2	128 6	140 3	148 7
200,000	32	23 4	36 1	45 9	54 1	62 5	75 0	83 4	91 8	100 0	112 7	120 11	129 3	141 10	150 2
250,000	32	31 4	45 4	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 8	151 0
300,000	36	28 4	42 5	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 9	151 1
400,000	40	30 0	46 6	44 6	52 10	61 2	75 0	83 4	91 8	100 0	113 10	122 2	130 6	138 10	152 8
500,000	44	29 9	49 2	43 6	51 10	60 2	75 0	83 4	91 8	100 0	114 10	123 2	131 6	139 10	154 7
600,000	44	38 6	58 2	} Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.											
750,000	50	34 9	57 5												
1,000,000	50	52 0	73 9												

Table II—Pittsburgh-Des Moines Standard Hemi-ellipsoidal Bottom Elevated Tanks



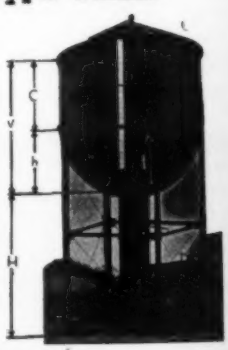
Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity											
				ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
25,000	17	11 9	15 5	46 4	51 8	71 4	75 0	.....	96 4	100 0	.....	126 8	...	.....	.....
30,000	17	14 7	18 6	46 1	51 5	71 1	75 0	.....	96 1	100 0	.....	126 5	.....	.....	.....
40,000	21	11 3	16 9	47 5	.....	.....	75 0	.....	97 5	100 0	.....	126 2	.....	.....	.....
50,000	22	13 2	19 0	.....	57 2	65 6	75 0	85 6	93 10	100 0	113 10	122 2	130 6	142 2	150 6
60,000	24	12 10	19 4	.....	56 6	64 10	75 0	84 8	93 2	100 0	113 2	121 6	129 10	141 6	149 10
75,000	26	13 6	20 5	.....	55 10	64 2	75 0	84 2	92 6	100 0	112 6	120 10	129 2	140 10	149 2
100,000	28	16 2	23 3	.....	51 6	64 7	75 0	81 1	93 0	100 0	114 7	118 0	126 6	143 0	154 10
150,000	34	14 10	25 0	46 9	55 1	63 5	75 0	83 7	91 11	100 0	112 1	120 5	128 9	140 6	148 10
200,000	38	15 5	27 0	46 11	55 3	63 7	75 0	84 6	92 0	100 0	113 9	122 1	130 5	143 0	151 4
250,000	40	18 1	30 0	47 5	55 9	64 1	75 0	85 5	93 9	100 0	115 1	123 5	131 9	140 1	153 1
300,000	40	23 11	34 0	49 4	57 8	66 0	75 0	87 4	95 8	100 0	117 0	125 4	133 8	142 0	155 0
400,000	46	22 9	34 11	48 10	57 2	65 6	75 0	87 8	96 0	100 0	118 2	126 6	134 10	143 2	157 0
500,000	50	23 9	37 0	49 8	58 0	66 4	75 0	81 2	89 6	100 0	112 8	121 1	129 4	146 0	152 8
600,000	55	21 9	39 7	} Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.											
750,000	60	22 4	42 4												
1,000,000	60	35 0	54 0												
1,000,000	65	26 1	47 7												
1,250,000	79	17 4	43 4												
1,500,000	70	37 8	60 0												
1,500,000	79	24 0	50 0												
2,000,000	90' 3"	22 6	50 0												

Table III—Double Ellipsoidal Tanks



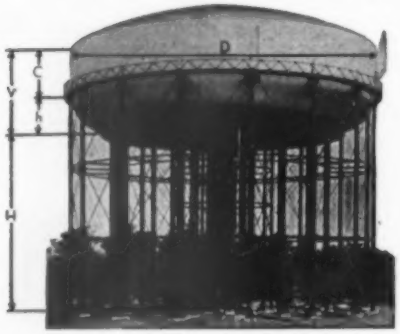
Capacity in U.S. Gallons	D	B	C	T	V	H
50,000	22'-0"	5'-10"	9'-4"	4'-4"	19'-6"	
75,000	26'-0"	7'-0"	9'-0"	5'-0"	21'-0"	
100,000	28'-0"	7'-0"	11'-1"	5'-7"	23'-8"	
150,000	34'-0"	10'-0"	8'-8"	6'-10"	25'-6"	
200,000	36'-0"	9'-0"	12'-11"	6'-9"	28'-8"	
250,000	40'-0"	10'-4"	11'-7"	7'-6"	29'-5"	Built
275,000	40'-0"	11'-11"	13'-9"	7'-6"	33'-2"	to
300,000	40'-0"	8'-7"	17'-11"	7'-6"	34'-0"	Order
350,000	44'-0"	14'-8"	13'-10"	8'-0"	36'-6"	
400,000	46'-0"	12'-2"	14'-9"	8'-8"	35'-7"	
500,000	50'-0"	15'-0"	14'-6"	9'-8"	39'-2"	
600,000	55'-0"	14'-4"	14'-0"	10'-0"	38'-4"	
750,000	60'-0"	15'-11"	12'-7"	11'-6"	40'-0"	
1,000,000	65'-0"	21'-8"	15'-9"	11'-0"	48'-6"	

Table IV—Railroad Type Tanks



Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft.	C in.	V ft.	V in.	H
20,000	15	10	9	16	2	
25,000	15	14	7	19	11	
30,000	17	12	7	19	0	Any height from 15' 0" to 40' 0" in multiples of 5' 0"
40,000	19	13	1	20	6	
50,000	21	13	1	21	1	
60,000	24	10	1	20	3	
75,000	24	15	1	23	10	
100,000	28	13	5	23	7	
150,000	28	14	2	24	7	
200,000	36	15	1	29	2	
250,000	38	17	3	33	3	
300,000	38	23	11	38	3	

Table V—Toroidal Bottom Tanks



Capacity in U. S. Gallons	Tank Diameter (D) when h = 10' 0" and V = 20' 0" ft.	in.	V = 25' 0" ft.	in.	V = 30' 0" ft.	in.	V = 35' 0" ft.	in.	H
750,000	82	0	73	2	66	8	61	8	
1,000,000	94	5	84	3	76	9	71	0	
1,250,000	105	4	94	0	85	8	79	2	Built
1,500,000	115	2	102	9	93	9	86	8	to
2,000,000	132	8	118	5	108	0	99	11	Order
2,500,000	148	0	132	3	120	7	111	6	
3,000,000	162	0	144	8	131	11	122	1	
4,000,000	186	8	166	9	152	2	140	9	
5,000,000	208	6	186	3	169	11	157	3	

Table VI—Steel Reservoirs

Capacity in U.S. Gallons	Diameter ft.	Height ft.	in.
50,000	20	21	6
60,000	22	21	6
75,000	24	22	6
100,000	26	25	6
150,000	30	28	9
200,000	34	29	9
250,000	38	29	9
300,000	42	29	3
400,000	46	32	6
500,000	50	34	6
750,000	60	35	9
1,000,000	70	35	0
1,500,000	80	40	3
2,000,000	95	38	3
2,500,000	110	35	6
3,000,000	120	35	9
4,000,000	130	40	9

WATER SUPPLY IN FIRE PROTECTION

Some Pointers and Considerations, Based Upon Experience and Observations

By RICHARD BENNETT
Hydraulic Engineer
City Engineer's Office, Phoenix, Arizona

FIRE protection has always been one of the primary responsibilities of municipal government. From the earliest ages the cities have equipped and maintained fire departments. Fire laws and building regulations for fire protection have been known since the earliest times. In fact, our word "curfew" comes from the Middle Ages when in France there was a strict law requiring all fires in residences to be put out at sundown.

The economics of fire protection revolve wholly around the insurance rates. Fire insurance is as old as fire protection, and today we find practically every property owner, whether in the small town or the big city, completely protected by it. The insurance premiums he pays are just as important to him as his city taxes, and in many places these premiums exceed his city taxes.

Fire Protection Based on Sound Economics

This means that there can be definite economic planning of fire protection. Additional fire protection naturally must raise the tax rate but if the insurance rates can be reduced in a greater amount than the increase in taxes, then the property owner has received a net benefit. If the cost of increased fire protection, as reflected in taxes, is greater than the saving in insurance rates, then it is obviously uneconomic.

We have a striking example of the working of this law of economics here in Phoenix when we submitted to our voters approximately a million dollars' worth of bonds for improving the water supply and fire alarm systems. It was proved that the reduction of insurance rates to be secured would more than offset the additional taxes caused by the bond redemption; therefore, it was economic to proceed with this work, and the voters gave their approval of the bonds.

Regardless of scientific advances, as yet nothing has been discovered which will put out fires so well as water. This means that if we are to put out fires and prevent conflagrations, we must have water available and plenty of it. The problem of water supply for fire protection is entirely different from that for domestic consumption. Fire protection is graded from two points of consideration: 1st, adequacy to meet requirements; 2nd, reliability to maintain adequacy. While both these requirements are desirable for domestic supply, purity is essential with softness and freedom from taste, odor and color being of prime importance. Domestic consumers will permit of low pressures and certain interruptions to continuity of supply, but such cannot be tolerated for fire protection.

For fire protection there must be an adequate supply of water to put out the worst anticipated fire, and this amount of flow must be available every minute of every day of the year.

This means that water supply systems for fire protection must be especially designed and for small towns will necessarily cost far more than if only domestic consumers were to be served.

Water Supply Counts for 34% in Insurance Ratings

The National Board of Fire Underwriters assigns 34% of the entire fire protection to the water supply. Another 30% depends on the fire department itself, and the balance is distributed among such items as climate, prevailing winds, fire alarm system, building ordinances, etc. Thus it is seen that fire insurance rates depend to a great extent upon the adequacy and reliability of the water supply.

With more than one-third fire protection requirements depending upon the water supply, it is imperative that municipal officials who are responsible for providing the most economic fire protection for their particular city have a working idea of the requirements which must be met to provide the necessary water for fire-fighting purposes.

To secure reliability the water must be available at all times. This may require a dual source of supply or may be met in many cases by providing an adequate amount of storage, utilizing two or more supply mains to the distribution system.

The factor of available quantity is usually the most difficult to meet. In practically all cities, including Phoenix, the original water supply system provided capacity for domestic use only and has been gradually converted into a fire protection system. In

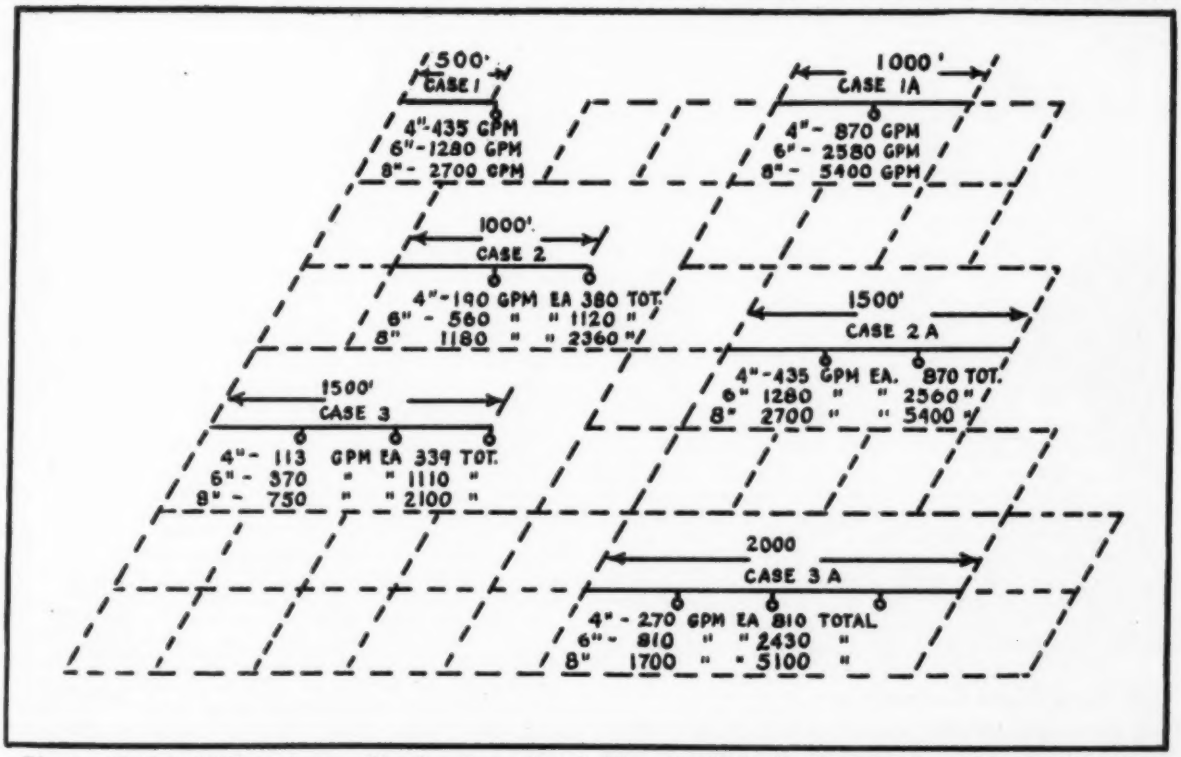


Fig. 1. Typical Gridiron Layout Showing Examples of Flow Available in Dead End and Connected Mains, Assuming a Uniform Pressure of 60 lbs. in Gridiron and 20 lbs. Minimum at Hydrants

general the gridiron mains and supply lines which were more than ample for domestic supply are totally inadequate for fire protection.

From the experience of many tests the Fire Underwriters have determined the amounts of water which must be available to cope with the fires which may be expected in cities of various sizes, a table of which is given in the Standard Grading Schedule issued by the Fire Underwriters.

Methods of Correcting Deficiencies Frequently Simple

Too often it is found that a city will receive many deficiency points which influence its fire rates due to the inadequacy of the distribution system to carry the required fire flows. For small towns the standard minimum fire flow is 1,000 gallons per minute in addition to the maximum daily domestic consumption. When small mains are installed and especially if any unconnected ends, commonly called dead ends, exist, then the capacity of the system is seriously impaired.

In order to show the serious effect of small dead end mains in the system, illustrative examples are given in Fig. 1.

The Fire Underwriters grade hydrants on the basis of being able to deliver not less than 600 gallons per minute.

In Fig. 1 the dashed lines represent a typical gridiron layout which has ample capacity to meet all consumption demands and it is assumed that the pressure in these mains, at any rate of flow in the examples given, is 60 lbs. per sq. in. and it is further assumed that all blocks are 500 ft. long. The capacity of mains is graded on the ability to maintain 20 lbs. per sq. in. pressure in the system at maximum flows.

The dead end main shown in Case 1 is 500 ft. long and for ordinary friction values has the following capacity:

Size of Main	Capacity G.P.M.	Fire Underwriters Required Capacity
4"	435	600
6"	1280	600
8"	2700	600

This shows that a 4-inch main will not deliver the required amount of water, and furthermore if a single valve is closed then all capacity of this dead end main is lost.

Case 1A shows the main extended such that it is fed from two ends. The capacity of this main is as follows:

Size of Main	Capacity G.P.M.	Fire Underwriters Required Capacity
4"	870	600
6"	2560	600
8"	5400	600

This indicates that the main has the required capacity but if a single valve were to be closed at either end then the 4-inch main would have insufficient capacity as shown in Case 1.

Cases 2 and 3 show dead end mains respectively 1,000 and 1,500 ft. long while Cases 2A and 3A show these mains extended and connected to be fed from both ends. The capacity in gallons per minute of these mains is as follows:

Case Number	Size of Main, Ins.	Capacity of Each Hydrant	Capacity of All Hydrants	Fire Underwriters Required Capacity
2	4	190	380	1,200
2	6	560	1,120	1,250
2	8	1,180	2,360	1,200
2A	4	435	870	1,200
2A	6	1,280	2,560	1,200
2A	8	2,700	5,400	1,200
3	4	113	339	1,800
3	6	370	1,110	1,800
3	8	700	2,100	1,800
3A	4	270	810	1,800
3A	6	810	2,430	1,800
3A	8	1,700	5,100	1,800

In grading a system all 4-inch mains and 6-inch dead end mains receive a deficiency rating, and these illustrative examples show the justification for such action, as they have inadequate capacity and reliability to meet demands which may be made.

The fire underwriters recommend that 6-inch mains be used only where they complete a good gridiron, and in no case in blocks 600 ft. or more in length; that not more than one hydrant be placed on a 6-inch main between intersecting lines, and not more than two hydrants on an 8-inch main between intersecting lines.

Some Case Records and Corrections

In many places it is possible to increase the reliability of the water works by simple changes in operating practice, as is illustrated in the actual case shown in Fig. 2.

This Arizona town has a gravity domestic supply with a stand by pumping system for fire service and was operated in case of fire by closing a manual valve in the tank line at Point "A" after the pumps were started. Due to weaknesses in the system, only one pump was operated, and in a throttled condition to control the pressure.

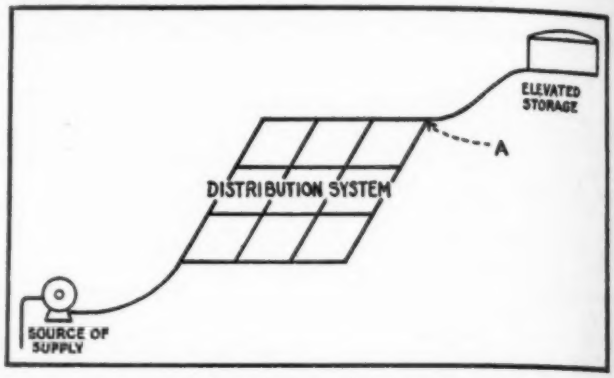


Fig. 2. A Good System (But subject to either right or wrong operation in fire service)

Differential tests on this system showed the city authorities the following startling condition:

	Static Pressure in System	Fire Flow Available Gal. per Min.
With tank only	43	628
With pump as for fire	68	475

In this case 32 per cent more water was available for fighting fires by depending on the tank rather than the fire pumps for supply. Under either method of operation this system was inadequate to meet the standard minimum of 1,000 gal. per min.

A second Arizona town has a pump capacity and storage capable of supplying about 5½ million gallons per day but is limited to and receives credit for fire protection for about 3½ million gallons per day because of small mains in the distribution system.

In order to receive the greatest benefit in fire insurance rates the fire protection facilities must be consistent as the protection features are graded on the basis of the weakest link or limiting factors. A town may have a strong pumping system and adequate mains but will receive a heavy penalty under reliability if the source of power for the pumps is dependent on a long single transmission line subject to lightning damage, and alos if the supply main from pumps to system is a long single main where a single break would leave the town without water. A good water works with no organized fire department will not receive any credit, and in turn a strong fire department and weak water supply receives a penalty for divergence.

A third Arizona town purchased a 500 g.p.m. fire engine pumper. The distribution system had a single 4-inch main in the main street. Tests on this main showed a fire flow available of only 90 g.p.m. No fire insurance reduction was received for the purchase of the fire engine as the system was inadequate to meet the demands of such equipment.

A fourth Arizona town purchased a 750 g.p.m. pumper. This town has a direct pumping system and on receipt of fire alarms raised pressure to such an exetnt that there was available in the principal business district about 2,000 g.p.m. at 50 pounds residual pressure. This town, due to existing conditions, was receiving credit for two-thirds of this flow for fire streams without pumper capacity or about 1,350 g.p.m.; therefore, the purchase of the pumper did not secure extra credit for fire protection.

The various units of the water works should be balanced in order to receive the most fire protection. A fifth Arizona town had a strong pumping capacity in four pumps which was materially limited by the inadequate supply main to the town. With this small main, only one pump could be operated at one time. With a larger and more adequate supply main, several pumps could have been operated simultaneously in case of a big fire, and credit would be received for the other pumps for fire protection.

These few cases have been cited to show the advisability of checking with the fire underwriters as to the wisdom of all expenditures *before they are made,* in order to receive most credit for changes in the system of fire protection. The fire underwriters will not act as engineers to design your system, but I have always found them quite willing to pass upon any proposed plans, giving their ideas as to whether this, or something else, seemed the most practical expenditure which the town could make to improve its fire protection per dollar of investment.

ROSS VALVE MFG. CO., INC.

TROY, NEW YORK

AUTOMATIC CONTROL & PRESSURE REGULATING VALVES

***For* Water Works and Fire Departments**

For accurate service, the automatic control and pressure regulating valves must be right as to type and size for the service required. Our W. R. Type, cast iron, bronze mounted valves in sizes from 4" to 30" are guaranteed for services for which they are designed.

Altitude Valves

Single Acting

Model 40 AWR — semi-throttling hydraulic control to prevent overflow of tank, standpipe or reservoir or to maintain a positive adjustable head for washing and filtering operations. Pilot adjustment range—4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Model 30 AWR—wide open or closed hydraulic control to prevent overflow of tank, standpipe or reservoir. Pilot adjustment range 4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Other single acting altitude valves combine back pressure or relief valve and pressure reducing functions.

Double Acting

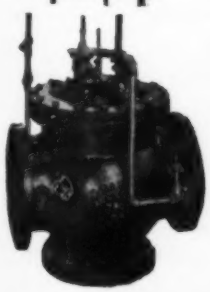
Model 40 DAWR—to prevent overflow in tank or reservoir and to allow return flow to distribution system when head on tank side is three inches higher than head of distribution system. These valves may be equipped with Remote Hydraulic and Electric Control. When required the return flow can be delayed for a predetermined pressure drop in distribution. Pilot adjustment range—4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Other double acting altitude valves combine many additional features to prevent dumping of tank, to retain supply on off peak loads and to make available maximum storage for peak load periods. Also a semi-throttling model for gradual closing of feed line and for maintenance of adjusted pressure on the distribution side. Can be equipped with secondary pilot to close valve if break occurs in distribution system.

Surge — Relief — Back-pressure Valves

Model 50 RWR—Single Pilot, Electric and Hydraulic Control—for protection against excessive pressures in distribution systems, supply lines and pump discharge lines. Installed in discharge line of deep well pump, provides constant back pressure to prevent overdrafting of the well. Pressure range in pilot—10 to 60 lbs., 20 to 150 lbs., 125 to 250 lbs.

Float Valve or Level Controller



Model 50 FWR—External Pilot Operated—to control main valve so that main stem operates wide open or closed. Pilot valve wastes to atmosphere contents only of operating chamber each time valve stem rises to open position. Maximum inlet pressure, 175 lbs.

Model 40 FWR—External Pilot Operated, Semi-throttling—for gradual closing of valve during last three inches before overflow.

Reducing and Regulating Valves

Model 40 WR—Single Pilot, Hydraulic Control—to maintain constant desired discharge pressure regardless of rate of flow or pressure on upstream side of valve. As a pressure reducing valve, operates to:

1. Control and regulate pressures in gravity and pumping systems.
2. Regulate flow between reservoirs and zones of different pressures.
3. Regulate fire flows between zones of unequal pressures.
4. Regulate pressures in filter wash lines and aerator nozzles.

Valves operate without waste of water to atmosphere and will not induce surge. Can be equipped with dual pilot to permit changing from one pressure to another by mere operation of a three-way cock for systems operating under different day and night pressures. Valves may be supplied with right-angle body. Pressure range outlet—10 to 60 lbs., 20 to 150 lbs., 125 to 250 lbs.

Model 40 WR—Single Pilot, Electric Remote Control—motor driven, geared to pilot adjusting tail screw, made with limit stops to prevent over-travel, and operated by push button switch.

Pressure Reducing and Reverse Flow Valves

Model 50 WR—Single Pilot, Hydraulic Control—for installation at dividing line between two zones to reduce pressure from higher zone, to function as a sleeping valve, discharging into low zone at a time of excessive draft, to permit flow from low to high zone when excessive draft in high zone reduces its pressure below that of the low zone as in case of fire. Pressure range outlet—15 to 60 lbs., 20 to 150 lbs. This valve may be equipped with dual pilot control to permit greater ranges in pilot control and to provide the assurance which goes with duplication and stand-by units.

FIRE DEPARTMENT SPECIALTIES

Portable Fire Hydrant Head for Pressure Reduction—Internal Pilot Operated—for attachment to high pressure main; carried on apparatus to fire, one man can attach (110 lbs. weight) in 18 to 30 seconds, four 2½" hose connections delivering independently from shutoff to full pressure and a fifth connection 2½" to 3" delivering full pressure.

Hose Valves for Pressure Reduction
Fire Engine Relief Valves

All Ross Valves Repaired in Line: Internal Packing Replaced Through Top of Valves.

R. D. COLE MANUFACTURING CO.

Est. 1854

Tanks, Towers, and Steel Plate Work
NEWNAN, GA.

5,000 TO 2,000,000-GALLON WATER TANKS

All shapes and sizes—The R. D. COLE MANUFACTURING CO. has developed a complete line of elevated steel tanks for water supply, both for domestic service and sprinkler requirements, ranging in capacity from 5,000 to 2,000,000 gallons.

The designs include the standard Hemispherical Self-supporting Bottom, the "Cole Ovaloid," Standpipe and many individual styles involving architectural treatment to satisfy local conditions, or to provide special shapes for advertising purposes.

STORAGE TANKS

Pressure tanks for storage of gas from digesters at sewage disposal plants so that excess output at peak loads can be used during off-peak periods. Chemical storage tanks, hot water storage tanks, tanks for bulk storage of oils and gas.

Designs Available for Any Service

1,000,000-Gallon "Cole-Shallow Depth" Tank

CONSTRUCTION FACILITIES

Fabricated Steel Plate—The R. D. COLE MANUFACTURING CO. has a fully equipped plant for the fabrication of riveted or welded steel plate. In addition to the construction of its regular line of horizontal return tubular boilers, oil storage tanks, tubular heaters, etc., the company is prepared to construct special tanks and apparatus of any specified metal plate.

Alloys and Lining for Processing Apparatus—The facilities and experience of the company enable it to fabricate special apparatus of all kinds for the processing industry using alloy steel plates, stainless steel, nickel-clad steel, etc., or linings such as lead, tin, nickel or Monel.

MAINTENANCE OF ELEVATED TANKS

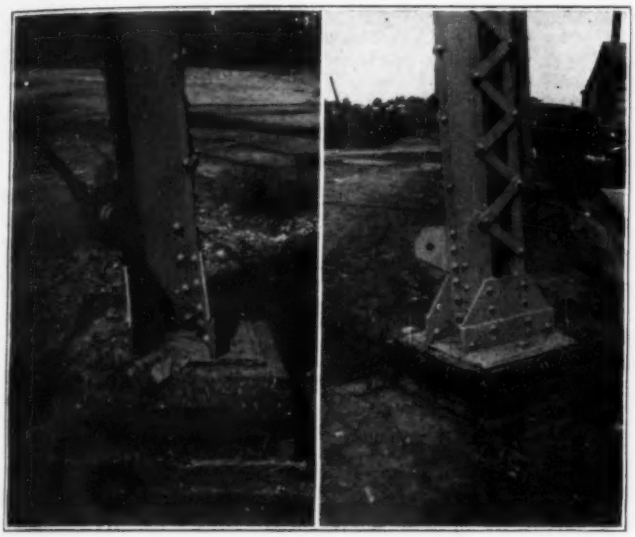
By JOHN M. PERRYMAN

Engineer, R. D. Cole Manufacturing Co., Newnan, Ga.

TANKS and towers are an important part of most water supply and fire protection systems, and should receive the same care and attention as other important parts of such systems.

It is generally known that corrosion of iron and steel is a silent enemy, working during both war and peace through all the years. The conversion of steel into iron oxide or rust is Nature's course in returning iron or steel into its original state.

Air and water coming into contact with steel starts this cycle of returning iron and steel to rust. Rust occupies more space and also weighs more than the steel destroyed, for it consists of hydrous iron-oxide which is 54 per cent iron, 20 per cent oxygen and 26 per cent water. Due to capillary action water will climb a rusty steel tank shell or column, regardless of its height. Corrosion of steel tanks can be caused and accelerated by the presence of acid fumes in the air, and particularly are tanks in large industrial areas thus affected. Also tanks located in areas of high humidity and along coastal waters, where high salt bearing vapors are present, are subject to accelerated rusting.



This Tank Has a Nice New Coat of Paint, But— an inspection by a qualified man would have avoided a dangerous condition. In very poor condition, the base of this recently painted tank was not given needed attention. It was not cleaned properly before painting and the base plate should have been grouted to shed water, prevent corrosion and frost spalling.

Another Bad Base Condition The base structure has been cleaned and painted but the brick foundation is badly in need of repairs. This picture also reveals the hazardous practice of removing the lower tower rods.

Surface Preparation

Tanks should be protected at all times from the elements that cause rust, using a paint that will protect the surface and present a favorable appearance. Steel can be protected at a reasonable cost by the use of rust inhibitive steel coatings. In preparing the surface the use of expensive sand-blasting is not necessary, nor chipping to the bare metal. The use of hand or power driven wire brushes is really all the preparation that is essential. The simple method of removing loose paint, scale and dirt by hand brushing, then applying a rust-inhibitor to seal the steel from the atmosphere will protect and prolong the life of your structure.

Loadings on Tower Members

As an example of the heavy loadings, on the tank tower structure, I might mention the 2,000,000 gallon tank in Charleston, S. C. The water and metal loading exceeds the weight of 6,000 Ford cars, and the 100,000 gallon tank at Mt. Pleasant, S. C., amounts to 325 Ford cars. You can see from this that the tower load involved in overhead tanks is appreciable, and must be dealt with according to a scientific business like procedure.

The Inspection

To assure long life and prevent, as near as practicable, the formation of rust, and in addition provide a safe structure, the tank should be drained completely, allowed to dry, and inspected by a competent inspector at intervals not to exceed five years.

These inspections should be made by no other than a skilled man who is thoroughly competent to detect weaknesses and pass upon their importance. This is not a matter which can be left to transient steeplejacks or traveling inspectors of unknown ability and integrity—the man should be a structural engineer. In locations where the water is highly aerated or contains particularly corrosive elements, the examination should be made more frequently than once in five years.

When an inspection is to be made, the fire chief and others dependent upon the water supply should be notified in order that they may not be dependent upon the tank for extra head and volume during the planned outage.

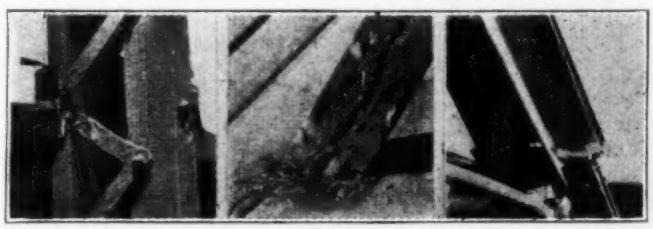
What to Look For

The inspection should consist of: first, an examination of all ladders for safety; especially examine for missing connecting bolts, conditions of lugs and rungs, etc. The revolving ladder on the roof should be inspected for a poor connection at the finial, also the ladders on the inside of the tank and rise should come in for thorough examination. Check condition of the roof and spider, and be sure that it will prevent the entrance of birds and other harmful matter, and that it will safely withstand sudden high winds. Examine the tank proper for loose scale and leaky rivets and seams.

The balcony floor is designed to resist the thrust of the columns and should be perforated at proper places so that water will not stand on the floor. Examine the hand rail for safety, also all rods, turnbuckles, clevises and pins.

Repairs and Replacements

Before repainting you should be certain that all badly corroded parts have been replaced or properly repaired. Look *under* the clevis pins and rod loops on your tank. The top side may be in excellent condition, but *the underside and partially hidden section may be found to be in a dangerous condition.* Examine the back surfaces of lattice bars, anchor bolts, the inside of boxed channel columns, pockets where batten plate connections and column bases form pockets for collecting trash and water without proper drainage. These enclosures may be cleaned and

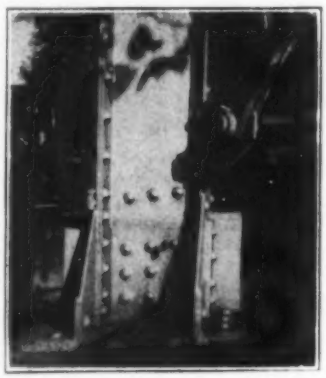


Some Bad Order Specimens
(Left) Lattice bars completely eaten away where building roof contacts the tower leg.
(Center) Another specimen of badly corroded tower leg.
(Right) This obsolete style of tower leg has all but failed. It buckled under the full load weight.

painted, then filled with concrete to a proper level at the top and shaped to shed water. Base plates should be grouted with sand and road oil mixed, or with asphalt.

Where angles or othter structural sections are separated by narrow spaces, rust can usually be removed by using narrow, bent scrapers, and the sides of the angles facing the narrow space may be painted with a spray gun. The present day manufacturer of elevated tanks endeavors to offer a tank design using open sections that can be readily inspected, cleaned and maintained.

If structural members of details affecting the strength of the tower are found to be in a condition such that they must be replaced, they should be renewed by a *recognized* tank designer, fabricator and *skilled* erectors. Diagonal wind rods should not be removed for cleaning and repairing, except when the tank is empty and on a calm day, and then only when adequate provision has been made by means of struts and guy wires to prevent a possible collapse of the structure.



An Important Hole to Keep Open

The arrow points to the deep hole in the boxed-in column section to drain water from this type of base.

The bases and base plates must be examined, and if the base is so built that it holds water (see illustration), drill a 1¼-inch hole through the channel boxed section to permit drainage. Trash should be removed at regular intervals. The base plates should be grouted with a mixture of sand and asphalt so water cannot run under the plates. The grout should taper off from top edge of plate to concrete pier.

There are a number of ele vated tanks built with auxiliary tanks of smaller capacity suspended underneath, also flat bottom tanks built on supporting grillage. When these tanks are inspected, look for badly corroded suspension rods and connections to the tank. They quite often are found in a dangerous condition. The steel grillage on flat bottom tanks is subject to heavy corrosion and only on careful examination will you find those connections that have become unsafe. There have recently been some tanks found in dangerous condition that were originally built without balconies and not sufficient reinforcing at the column connections. The shell plates have actually broken, due to over-stressing and fatigue of the metal.

Concerning Rivets and Seams

Much has been said about leaking rivets and seams. The facts are that in most cases the importance of this is exaggerated and sometimes used by unscrupulous repairmen as an entry and excuse for expensive repair work.

Loose rivets can be caulked just as effectively as can leaky seams. Don't let anyone tell you that because the head of a rivet is badly pitted that it must be removed and a new one driven. Remember that a rivet head is to hold the plates firmly together, and other than holding a small tension between the plates, a corroded head does not seriously impair the strength of your structure. *It is the shank of the rivet that really does the job.* Furthermore, when a rivet is knocked out, you loosen at least eight additional adjoining rivets, thus a larger repair job has been created. Be careful!

Cleaning

After all of the above procedure has been carried out, the tank should be thoroughly cleaned both inside and outside, as well as the tower and other parts of the structure. Paint or mill scale which adheres firmly to uncorroded steel should *not* be removed, but these surfaces should be cleaned to remove all loose dirt or sediment. Where extensive pitting of the steel beneath several coats of paint is encountered, this portion should be vigorously wire brushed with a power tool to prepare properly for the new coat of paint.

If the tank has a large steel riser (36-inch diameter or larger), all sediment can be removed from the base by the means of the washout valve in the base of such risers. However, if the tank has a small cast iron or steel riser of from, say, 8 to 12 inches, it will be necessary to bail the sediment from the bottom of the tank, since these tanks are in general without washout valves.

Remember to repack the expansion joint and replace all brittle and leaking gaskets at manholes. Frostproof casings should be repaired or replaced; or, even better, remove both pipe and casing and have a 36-inch steel riser installed in its place if the size of the installation will justify it.

Painting

Best results from painting are obtained when the outside temperature is above 50 F. and the temperature of the paint and surface to be painted are the same. Painters should be cautioned not to allow trash, paint or other material to drop down the riser while they are cleaning or painting. A sheet of heavy paper may be tied over the small riser, or a deck may be built across a large riser pipe.

Interior

During the summer it is best to paint tank interiors at night in order to avoid uncomfortably high temperatures. Paint dries more quickly on the inside if the manhole cover is removed and the roof hatch is left open. Forced air circulation has a definite advantage in expediting the painting job, and it should be remembered that forced circulation adds greatly to protection of the painters and accelerates drying.

It is recommended that the inside of the tank, riser and underside of the roof be painted with two complete coats of red lead and a final coat of black interior tank finish. This finishing coat should be of the type that does not impart any taste, odor, or discoloration to the water.

The coat of black interior tank finish is actually to protect the red lead, and, of course, the red lead is to protect the steel.

Exterior

Paints tend to loose their imperviousness when submerged in water for long periods, such as on the inside of tanks. It is suggested that 10 per cent by weight of litharge be added to resist the softening action and hasten the drying. The litharge may be mixed in a small amount of linseed oil and then added to the red lead as required.

The outside should be painted with a coat of either red lead or gray lead, followed by two coats of aluminum. It is also suggested that you paint all abraised surfaces with two touch-up coats prior to the finish painting with aluminum.

For best results, the final coat inside the tank should be allowed to dry *at least one week* before admitting water.

Safety and Cleanliness

Paint thinned with naphtha, benzol, toluol or other liquids which give off toxic vapors are hazardous to life when used in confined spaces such as inside of a tank. They should be used only by experienced painters who are thoroughly familiar with their proper applications and the hazards involved. Forced air circulation inside the tank and gas masks are essential where such dangerous materials are employed.

After painting, particular care should be taken to make sure that all planks, scaffolding, rope, paint cans, brushes, and other material are removed from inside the tank and riser. This having been done, you should refill the tank, sterilize it in accordance with the Board of Health requirements, and restore service as soon as possible, considering good workmanship and proper drying as the first essentials.

Foundations should be examined, and if showing signs of deterioration should be carefully pointed up with a cement mix consisting of one part cement and one part of sand. There have been a number of foundation piers built of brick or stone. These should receive extra attention.

A typical specification for tank painting follows, and we believe that it will eliminate any possibility of the tank owner suffering from some unscrupulous contractor, holding him responsible for charges other than cleaning and painting, unless such extras are authorized in writing. Your attention is further directed to the practice made by most tank fabricators and erectors of making tank inspections at a nominal charge and

giving a written report of work that, in their opinion, is actually necessary.

REPAINTING ELEVATED TANKS
(A Pattern for Specifications)

Bids are to be received for the furnishing of the necessary labor, tools, equipment and materials to clean and paint Elevated Steel Water Tank and on a steel tower elevating the bottom Steel Tower of ——— gallons capacity —— ft. —— in. above top of foundations, and/or Flat Bottom Steel Water Reservoir of ——— diameter x ——— height.

General: The inside of the tank proper and underside of roof is to be carefully examined and all loose paint, scale, rust and blisters are to be removed with scrapers and power wire brushes and the surfaces thoroughly dried. Paint or mill scale which adheres firmly to uncorroded steel need not be removed, but the surface should be cleaned to remove sediment and dirt. If there is extensive pitting of the steel, this is to be brought to the attention of the inspector for whom the work is being done.

The spider rods, inside ladder, or any oher inside structural details, such as the inside of the large steel riser pipe, is to be thoroughly cleaned as previously mentioned before any paint is applied.

All dirt and sediment collecting at the base of the riser is to be removed.

Any brittle or leaking gaskets at the manhole, washout valve or other openings are to be replaced with new gaskets of equal or better materials.

The inside of the tank and large steel riser after being prepared as heretofore mentioned and approved by the inspector, are to be given one coat of red lead paint with 10 per cent by weight litharge added to offer resistance to softening action of the water and dry more quickly. After this red lead coat has become thoroughly dry, a coat of black interior tank finish paint is to be applied on the inside for the finish coat.

The outside of the tank is to be examined and cleaned as indicated for the inside, with especial attention being given to those parts of the tank structure which are difficult to clean, such as around the clevice pins and end of diagonal wind rods, anchor bolts or back surfaces of lattice bars or columns, inside channel columns near foundations, inside surface of members composed of angles which are separated by thin lattice bars, washers or short pipe.

If members or details effecting the strength of the structure are found seriously corroded, this should be brought to the attention of the inspector. Diagonal wind rods or other members should not be removed for cleaning, unless the tank is empty and adequate provision is made to prevent the structure from collapsing.

After the outside has been thoroughly cleaned, a touch-up coat of red lead is to be applied to all surfaces where the paint has been removed, and then the entire outside of the tank and tower is to be given two coats of aluminum paint of color selected by the purchaser and of a kind made purposely for application to outside of steel water tanks.

The contractor for this work is not to apply any paint, unless the outside temperature is above 50 degrees, and paint and surface of the steel should be approximately the same temperature.

Provision is to be made for the safety of the men, providing proper ventilation for working on the inside, and comply fully with all local and state laws; Workmen's Compensation, Public Liability and Property Damage Insurance are to be carried with $10,000.00 and $25,000.00 limits.

Certified copies of policies in force to be attached to contract.

The contractor is to employ only skilled elevated tank painters, and no other work except the above cleaning and painting is to be done, except with written approval.

Upon completion of the painting, the contractor is to remove or dispose of all rubbish or other unsightly material caused by their operation and leave the premises in as good condition as it was found.

Terms of payment: Net cash on completion and acceptance of work.

Additional Comments

Tanks with small cast iron risers and wooden frost casings should be examined and expansion joints repacked.

If hot water or steam pipes are in poor condition, they should be replaced.

Consult your insurance company and advise them when the tank will be out of service and length of time out of service.

If the tank is a municipal water supply unit, notify the local fire authorities when the tank will be out of service, so they will not be dependent on this volume of water for fire protection.

MAKING PIPE BUSHINGS FROM STANDARD PIPE

A Handy Kink

DO YOU know that first class pipe bushings can be made out of standard pipe? Many users of pipe don't know that it can be done. Or, if they know that it can be done they don't know the correct size of drill to use for tapping. I have occasionally made bushings out of pipe, but each time I found it necessary to first look into my handbook for the drill size to use and that is so much trouble that it is frequently easier to go to the store and buy a new bushing. Recently, though, I collected all of the data together for all bushings that can be made out of ordinary sizes of extra heavy and double extra heavy piping, compiled the figures in tabular form, and here they are.

For example, to bush from ¼" to ⅛" get a piece of ¼" extra heavy pipe sufficiently long for cutting the outside thread. Then cut the end off to the desired length, drill or ream with a 21/64" drill (diameter of drill 0.328") and then tap with a ⅛" pipe tap. That's all there is to it.

This accompanying table tells the complete story for all ordinary sizes: Note that in one case, ⅜" to ¼", the internal diameter of ⅜" extra heavy pipe is such that no drilling is necessary.

Note also that in bushing from ½" to ⅜" either extra heavy or double extra heavy piping can be used.

To Bush From	Use This Size Pipe	Use This Size Drill or Reamer
¼" to ⅛"	¼" X	21/64" drill = 0.328"
⅜" to ¼"	⅜" X	None.
½" to ⅛"	½" XX	21/64" drill = 0.328"
½" to ¼"	½" XX	27/64" drill = 0.422"
½" to ⅜"	½" XX	9/16" drill = 0.562"
½" to ⅜"	½" X	9/16" drill = 0.562"
¾" to ⅜"	¾" XX	9/16" drill = 0.562"
¾" to ½"	¾" XX	11/16" drill = 0.688"
1 " to ¾"	1 " XX	29/32" drill = 0.907"
1¼" to 1 "	1¼" XX	1/18" drill = 1.125"
1½" to 1 "	1½" XX	1/18" drill = 1.125"
1½" to 1¼"	1½" XX	1-15/32" drill = 1.468"
2 " to 1½"	2 " XX	1-23/32" drill = 1.72 "
2½" to 2 "	2½" XX	2- 3/16" drill = 2.187"
3 " to 2½"	3 " XX	2- 9/16" drill = 2.562"
3½" to 3 "	3½" XX	3- 3/16" drill = 3.187"
4 " to 3½"	4 " XX	3-11/16" drill = 3.688"
4½" to 4 "	4½" XX	4- 3/16" drill = 4.187"
	X = extra heavy pipe. XX = double extra heavy pipe.	

BINS, Storage
BREECHING, Steel
CHUTES, Steel
FILTRATION PLANTS
FLUMES, Iron and Steel
GAS HOLDERS
HOPPERS, Steel
PENSTOCKS
PIPE, Riveted steel
PIPE, Welded steel

CHICAGO BRIDGE

Chicago.....2198 McCormick Bldg. Greenville.....York Street
New York....3390—165 Broadway Bldg. Birmingham.....1586 North 50th St.
Cleveland.....2262 Guildhall Bldg. Tulsa.....1646 Hunt Bldg.

Plants in CHICAGO, ILL.; BIRMINGHAM, ALA., and GREENVILLE, PA.

Complete facilities for designing, fabricating and erecting all types of elevated tanks, storage tanks, pressure vessels and steel plate work, riveted or welded, are available at our plants. We invite inquiry from municipal officials and water works engineers who are planning the installation of steel plate work. When estimates are desired on tanks, state capacity, height to bottom for elevated tanks, and describe location.

RADIAL-CONE BOTTOM TANKS

The radial-cone bottom design was developed to permit the construction of large capacity tanks with a small range in head. Radial-cone tanks are of sound structural design. They present a pleasing appearance. Construction details such as tower bracing, hand railing, etc., may be varied to secure the desired architectural effect. The accompanying table indicates the proportions for the various capacities.

Shown here are four Horton radial-cone bottom elevated tanks.

Above Left: 1,000,000-gal. tank at Tucson, Arizona.

Above Right: 1,500,000-gal. unit at Indianapolis, Indiana.

Extreme Left: 400,000-gal. tank at Olney, Illinois.

Left: 1,500,000-gal. unit at San Antonio, Texas.

STANDARD RADIAL-CONE SIZES

Capacity (Gallons)	Diameter of Tank	Depth of Tank
500,000	61′	25′
750,000	76′ 8″	25′
1,000,000	87′	25′
1,500,000	106′	25′
2,000,000	122′	25′

A booklet is available, showing various sized radial-cone bottom tank installations.

ELLIPSOIDAL-BOTTOM ELEVATED TANKS

This type of tank is built in standard sizes as shown in the table at the right. The tank diameter is relatively large and the depth shallow, reducing the variation in pressure between upper and lower water levels. Ellipsoidal-bottom tanks are available with two types of roofs: cone or ellipsoidal. A typical cone roof tank is illustrated below at the right, and tanks with ellipsoidal roofs and bottoms are shown directly below. This design provides a pleasing, modern appearance.

ELLIPSOIDAL-BOTTOM TANK SIZES

Nominal capacity, gal.	Tank dimensions			
	D	H	B	K
40,000	20′0″	13′9″	5′0″	18′9″
50,000	22′0″	14′0″	5′6″	19′6″
60,000	24′0″	14′0″	6′0″	20′0″
75,000	26′0″	15′0″	6′6″	21′6″
100,000	28′8″	16′0″	7′2″	23′2″
125,000	28′8″	21′2″	7′2″	28′4″
150,000	34′0″	16′6″	8′6″	25′0″
200,000	38′0″	17′6″	9′6″	27′0″
250,000	40′0″	20′0″	10′0″	30′0″
300,000	41′0″	23′9″	10′3″	34′0″
400,000	47′0″	23′3″	11′9″	34′11″
500,000	51′0″	24′3″	12′9″	37′0″
600,000	54′0″	26′3″	13′6″	39′9″
750,000	54′0″	32′0″	18′0″	50′0″
1,000,000	60′0″	34′0″	20′0″	54′0″
2,000,000	80′0″	35′6″	26′0″	61′6″

Height to bottom—any even foot.

50,000-gal. Montrose, Minn.

200,000-gal., Hollywood, Fla.

500,000 gal., Bristol, Penna.

40,000-gal., Warrensburg, Ill.

& IRON COMPANY

Houston.....5615 Clinton Drive
Philadelphia....1644—1700 Walnut St.
Washington.....330 Bowen Bldg.
San Francisco.....1083 Rialto Bldg.
Havana.....402 Edificio Abreu

In Canada: HORTON STEEL WORKS, LIMITED, Fort Erie, Ontario

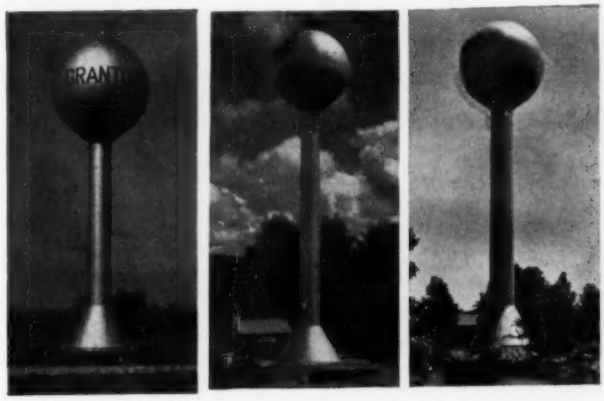
PRESSURE VESSELS, Welded
RESERVOIRS, Steel
RECEIVERS, Air
SMOKE STACKS
STANDPIPES

STEEL PLATE WORK
TANKS, Elevated Steel
TANKS, Storage
TANKS, Surge
TANKS, Washwater

WATERSPHERES

This relatively new elevated storage tank design has attracted wide public interest because of its unusual shape. Engineers and water works operators have found that Waterspheres embody highly functional construction. A single cylindrical column provides an economical means of supporting an elevated tank. The plain plate surfaces are easier to maintain than the customary structural columns. Waterspheres have been installed in many municipalities, in sizes ranging from 40,000 to 250,000 gallons.

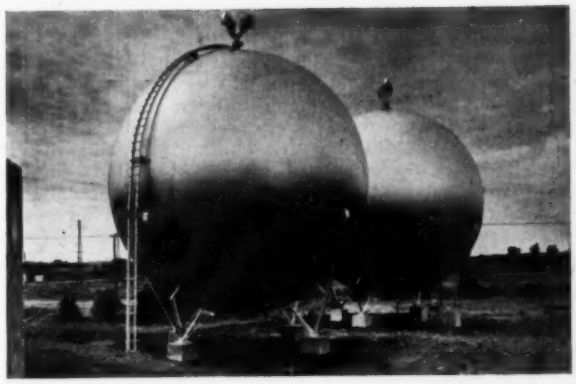
Three typical Watersphere installations are shown at the right. Capacities and locations are as follows: (left to right) 50,000-gal., Granton, Wisconsin; 75,000-gal., Watsonbury, N. C.; 150,000-gal., Kent, Ohio.



MISCELLANEOUS TANKS

HORTONSPHERES—SEWAGE GAS HOLDERS

When gas from digesters at sewage disposal plants is utilized, excess quantities produced during peak periods can be stored advantageously under pressure in a Hortonsphere for use during off-peak periods. Hortonspheres are relatively small in size and pleasing in appearance. We also build conventional lift-type gas holders. The two Hortonspheres shown at the right are located at the Rock Island, Ill., sewage disposal plant. They have a capacity of 50,000 cu. ft. each and operate at 50 lbs. per sq. in. pressure.

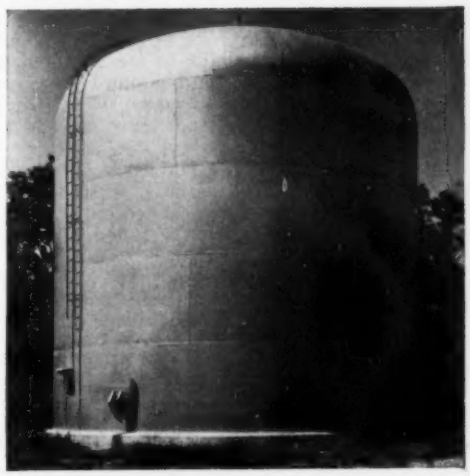


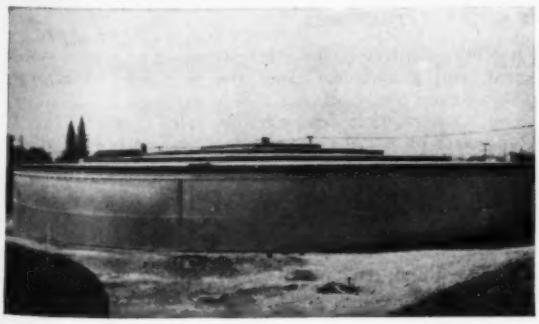
WASHWATER TANKS

We build ellipsoidal, radial-cone or special shaped tanks to give exactly the capacity, head, and pressure variation required for washing filters. Shown at the left is a 100,000-gal. washwater tank at Michigan City, Ind.

FLAT BOTTOM WATER STORAGE TANKS

Shown at the right is a 250,000-gal., ellipsoidal-roof, flat-bottom water storage tank at Kent, Ohio. We build tanks of this type in any diameter, capacity or height to meet your requirements.





RESERVOIRS

Where natural elevations are available, flat-bottom steel reservoirs provide efficient gravity pressure. They are built in standard sizes or special designs to meet your requirements, of riveted or welded construction, with or without roofs.

Left: One of two 2,300,000-gal. all-welded steel water reservoirs installed at Alhambra, Calif.

TANK MAINTENANCE

Good and Bad Practices

By WALKER B. DAVIS

Counsel
Chicago Bridge & Iron Company Chicago

A LAWYER appearing before a group of engineers to talk about good and bad practices in maintenance of elevated tanks owes such an audience an explanation, particularly if he has never spent even a summer vacation working on a water tank. I may as well confess at the outset that I have no first-hand knowledge of tank maintenance, and not very much second-hand knowledge, so that I have had to borrow liberally from the writings and speeches of members of our company's operating department in order to have anything at all to say about the good practices in this field. The reason I am here is that in the course of my legal activities I have learned something about some very bad practices from which the owners of elevated tanks have suffered and I have been discussing with the officers of this Association ways and means of discouraging these practices.

Everyone knows, of course, that steel will rust if it is not painted and I am sure it is generally appreciated that an elevated steel water tank should be cleaned and painted periodically. There are many reputable companies and individuals who do this work and do it well. A few unscrupulous concerns, however, have made contracts for cleaning and painting tanks an excuse for doing a great deal of unnecessary work which they call "repairs" and for which a considerable number of municipalities have paid many times what it would have cost to have their tanks cleaned and painted by honest contractors. These concerns have extended their activities into almost every section of this country. Their energy, their skill as salesmen—and, I may add, their ability, in court—is really amazing. Indeed, it would seem that they could earn an honest living with much less effort, and certainly with much less risk, but apparently it is more fun to operate a racket.

The Rivet Racket

Cleaning and painting a tank is merely incidental as far as these racketeers are concerned. It serves as a convenient starting point for their real objective. They take a cleaning and painting contract at a low figure, but they slip in a clause which permits them to replace loose and defective rivets, and to weld pits, at so much per hour, or so much per rivet, or on some other basis which makes it profitable for them to replace as many rivets and weld as many pits as possible. Once they get such a contract, they do a minimum of cleaning and painting, and concentrate their efforts on cutting out rivets as fast as they can. When they have cut out so many rivets that the tank is completely unserviceable, they sometimes demand a written order to replace the rivets they have cut out, and they tell the municipal authorities that if they do not get such an order they will go away and leave the tank as it is. This threat, of course, is an effective one, because if it is carried out the town will be without water until someone else can be found to put the tank back into service.

The village of Dexter, near Ann Arbor, Michigan, has an elevated water tank that was built about 1927. In 1940 a tank repair company persuaded the village authorities to enter into such a contract as I have described. The painting was done without adequate cleaning of the steel, so that less than a year later it was possible to remove large pieces of paint with one's fingers, and there was a good deal of rust on the inside of the pieces that were removed. There were about 4,275 rivets in the shell and bottom of the tank. It seems hard to believe but actually 4,198 of these rivets were cut out and replaced—in other words, all but 77 of the rivets in those parts of the tank on which any work was done. The village received a bill for about $4,300 covering over 1,700 man hours of extra work which was done under the supposed authority of the clause authorizing the replacement of defective rivets, etc. The village had already paid $1,300 before the fraud was discovered, but refused to pay the balance, and the tank company brought a suit to enforce payment. The case was tried in the Circuit Court at Ann Arbor. The evidence disclosed that an inexperienced foreman had been put in charge of the work and that, as the trial judge said, the service was less than valueless—it actually damaged the tank. Fortunately, the trial resulted in a decision in favor of the village, but the village was put to a great deal of unnecessary expense, and the village officials were greatly inconvenienced, even though the contested bill did not have to be paid.

Things like this have happened in a number of other towns in various parts of the country. There is a lawsuit pending now in which the town of Illmo, Missouri, is seeking to recover damages because a large number of sound rivets were cut out of its tank and the town had to get someone else to restore the tank to working order after these depredations had been committed. The town of Enfield, North Carolina, had a somewhat similar experience. The State of Michigan had to defend itself in the Court of Claims against a large bill for the removal and replacement of rivets that were not defective. And so the list might be continued. If the public officials discover that they have been imposed upon before they have paid the bill, they can defend themselves in court, but that is not a very satisfactory remedy, as a lawyer must be the first to admit. The real solution, of course, is prevention and I know of no way to prevent such occurrences except to familiarize municipal authorities and water works engineers with the facts and keep repeating them almost incessantly, so that the things one group of officials has learned will not be lost sight of when their successors take office.

Characteristics of Rivets That Should Be Better Understood

I assume most of you know that rivets in elevated water tanks are quite commonly driven with flat heads on the inside of the tank. These flat heads have rough, irregular surfaces, and after they get a little rusty, it is easy for an unscrupulous person to lead municipal officials, and others inexperienced, to believe that the driven head on the inside of the tank was originally round and smooth, like the manufactured head on the outside, and that most of the inside head has rusted away. Actually, of course, the amount of steel lost by rusting is insignificant and the rivet head is practically as good as it ever was. Some of my colleagues have compared the weight of rivets driven experimentally with the weight of rivets which one of these repair companies had cut out as defective and have found that there was very little difference. In the Dexter case, witnesses testified that the hammer marks which were made when the rivets were originally driven could still be seen on some of the heads that had been cut out of the tank.

Even if the inside rivet head has largely rusted away, the rivet does not need to be replaced, as long as it stays in its hole and does not leak. While the rivet head may be for the purpose of water-tightness, it is the shank of the rivet that carries the shearing stresses. The important point to remember is that if the tank does not leak the rivets are not defective, and there is no occasion to replace them until leaks definitely develop. Even then remedies other than replacement are available and effective.

Occasionally small leaks develop around rivets where the steel of the rivet head is not in contact with the steel of the tank plates. Except in unusual cases, where corrosion is very severe, such a leak can easily be stopped by the use of ordinary hand caulking tools. It is not necessary to replace the rivet and the chances are that anyone who wants to replace it either doesn't know his business, or knows it too well, and wants to take advantage of the municipal officials with whom he is dealing. In either case, he is not the sort of person who should be allowed to do any work on an elevated tank.

Plate Pins and Correctives

If a tank has been neglected, the steel plates may become pitted because of rust, and in extreme cases the rust may have eaten completely through the plate, leaving a hole through which water can escape. Such a condition can be temporarily corrected by inserting a patch bolt which will close the hole and will often suffice for several years. Welding of pits and leaks is of doubtful value, because the heat which is generated in the process of welding often causes new leaks, and even if a considerable area is welded, other leaks are apt to appear relatively soon. In ordinary cases, where the pits are not serious, the best procedure is to clean them and repaint them without attempting to fill them. The only complete remedy in serious cases, of course, is the replacement of the

plates which are involved and that should be done only by someone who is thoroughly competent to do it.

Spider Rods Deceive

Another source of income to unscrupulous tank repair companies is the replacement of spider rods. While a tank is being erected these rods are placed across the top of the tank shell under the roof, like the spokes of a wheel, but they are really nothing more than pieces of erection equipment. They have no permanent value to the tank. Spider rods rust out rather rapidly, because they are alternately under water and above it, and consequently they can be pointed out to the uninitiated as horrible examples of the things the rust is doing to a tank. They look enough like structural elements to convince many people that they are necessary to the stability of the tank, whereas in fact they are of no importance once the tank has been built, and there is no occasion whatever to replace them if they rust out. The suggestion that the spider rods need to be replaced ought to be a danger signal and ought to lead municipal officials to avoid any dealings with the man who makes it.

Another favorite scheme of the racketeers is to convince the owner of an elevated tank that the sway rods are in need of adjustment and that the tank is likely to collapse if they are not tightened before the wind starts to blow. This is very definitely a false alarm. We have never heard of a case where adjustment of sway rods was necessary to prevent a tank from collapsing. The rods are carefully adjusted when the tank is built, so as to distribute stresses uniformly throughout the tower, and ordinarily the original adjustment is sufficient. If any subsequent adjustment is needed, the work should be done by an expert or else the original balance will be disturbed and serious distortion may result. The itinerant tank fixer is not very likely to be competent to do that sort of work.

One of the tricks of these outfits is to change the names under which they operate after the news spreads that one or two towns have been defrauded. I know of one man who operated for a while under one firm name, then went to work for his wife, who operated under a different firm name, and finally had his own name legally changed and began to operate from new headquarters under still a different firm name.

Longevity of Water Tanks

If an elevated water tank is thoroughly cleaned and painted with reasonable frequency it should have a very long life. A recent survey of 111 tanks and standpipes along the New England seacoast, where weather conditions are most unfavorable and waters are corrosive, showed that 67 tanks were still in use, and that their average age was already 47 years. Only 12 standpipes had become unsafe after 35 to 40 years. The other 32 no longer in service had been superseded by elevated tanks or had become inadequate to meet increasing demands for water. It is very unlikely that even a tank which is 30 years old will need extensive repair, unless it has been very badly neglected, and if it has been neglected, the neglect will be evidenced by leaks if the consequences have been at all serious.

Remedies for Weeping Tanks

If a tank does develop leaks, the remedy is usually simple and inexpensive. The safest thing to do in such a case is to notify the company which built the tank and and ask for an inspection. The builder will be glad to inspect the tank for a nominal charge and will tell the owner what is necessary to put the tank in good condition. Ordinarily the builder will not be interested in cleaning or painting the tank but I am sure that any company which builds tanks has enough interest in the tanks it has built to be willing to make an inspection and advise the owner what is needed to return it to first class condition. If something goes wrong with an automobile, you go back to the man who sold it to you, and the same practice is advisable in the case of a water tank.

Need for Standard Specifications Covering Cleaning and Painting

When the activities of unscrupulous tank repair companies were brought to the attention of the American Water Works Association, the Board of Directors wisely concluded that it would not be sufficient merely to issue a warning, but that something constructive was required in addition to the warning. It was decided that standard specifications for cleaning and painting elevated tanks and standpipes should be prepared and furnished to municipalities, so that it would not be necessary for the municipal officials to rely for specifications on those who solicit maintenance work. Mr. Ralph Green, of our company, has drafted some specifications which I believe the A.W.W.A. Board of Directors is considering amongst others. I am not going to present these specifications at length because they are tentative and the scope of the final specifications has not yet been determined. However, since President Howson has suggested that I comment on them, they will be summarized briefly.

The inside of a tank is actually more apt to be damaged by rust than the outside. Before the paint is applied, all dirt, rust, loose mill scale and loose paint should be removed by means of scrapers and wire brushes so that the surface of the steel will be clean and smooth. If the condition of the steel is such that scrapers and wire brushes will not clean it properly, it should be sand-blasted, using chiefly silica grains as sharp and coarse as practicable. *No greater area should be sand-blasted on any one day than can be painted on the same day.* Whether the steel is cleaned with scraper and wire brushes or by sand-blasting, all rust which forms on the cleaned surface should be removed before any paint is applied.

If the old paint is in fair condition, only one new coat may be necessary, but if the steel is exposed in spots, these spots should be given a patch coat before the finish coat is applied. If the surface is in bad condition, there should be a primer coat and a finish coat, and in any event the amount of painting to be done and the number of coats should be carefully specified.

Opinions will differ, of course, about what kind of paint to use. Naturally, a good quality of paint made by a reliable manufacturer should be specified, and price should definitely not be the controlling factor in making the selection.

The cathodic method of protecting the inside of a tank against rust is a recent development which, I believe, eliminates the necessity of painting in some circumstances, but unfortunately I am not familiar enough with this method to discuss it and I mention it merely in order that it not be overlooked.

The specification should, of course, require a workmanlike job and it is advisable to include a provision that each coat must be allowed to dry thoroughly before the next coat is applied and that paint shall not be applied during wet or foggy weather or when the temperature of the air is below 50° Fahrenheit. I think we all know that weather conditions must be reasonably favorable in order to get satisfactory results in painting.

Frequency of Renovation and Selection of Contractor

If an elevated tank is thoroughly cleaned and painted at least once every four or five years, it is not likely to require much other maintenance and it is not likely to need repairs. Rust is the principal enemy of such tanks and its ravages can be checked by periodic cleaning and painting. If, however, repairs do become necessary, they should not be done as an incident to a painting contract. The tank should be inspected by the builder or some other competent party, the exact repairs that are necessary should be determined and one or more proposals for doing that particular work should be obtained. The work should be let only to a qualified, experienced concern of recognized standing which is known to the municipal authorities and which can give satisfactory references. Before signing a contract with a concern which is not well known to be reliable the references which are given should be checked, because the unscrupulous repair companies are both ingenious and daring, and they may not hesitatae to name as references people who they know will not recommend them should an actual inquiry be made. I know of one case where our own company was given as a reference by a man who I am sure knew that we had a good deal of unfavorable information about him and that we would not hesitate to give this information if we were consulted.

Even in ordinary times, an elevated tank is an asset which should be protected and made to serve a community for many years. At present, when the use of steel for elevated tanks is severely restricted, it is more important than ever to see that existing tanks are well cared for. I am sure you will agree with me that it is a serious crime to waste steel by removing rivets that are still serviceable. I hope that you will cooperate with this Association and with the various Municipal Leagues and Better Business Bureaus in exposing the rackets I have described and giving public officials the facts as to what is necessary for the maintenance of elevated tanks and what is not only unnecessary but positively harmful.

If you know of any cases where municipalities have been imposed on, and if you are in a position to substantiate the facts, I am sure the American Water Works Association would like to hear from you. If you have or can obtain any evidence of violation of State or Federal law, I think you will be doing a public service by turning over such evidence to the proper authorities, so that they can prosecute the offenders and check the racket.

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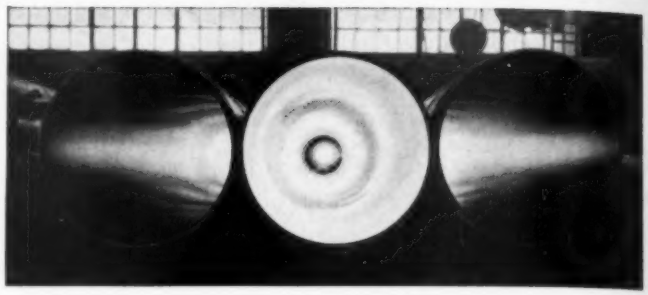

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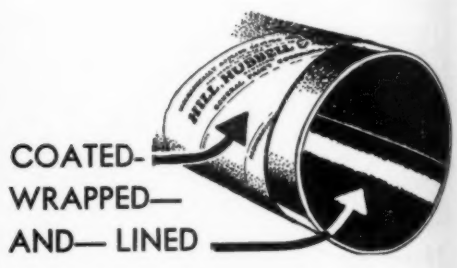

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CATHODIC PROTECTION

For Water Tanks and Submerged Metallic Parts

By EARL E. NORMAN, Superintendent
Department of Public Utilities, Kalamazoo, Michigan

DURING the past few years there has been a great deal of interest shown in the process of electrically controlling internal corrosion of water tanks. I have been asked to outline some of the principles involved, and to indicate some of the results that may be expected from such a process, as well as gather information from representative installations of the process.

Definitions

In order to prevent any misunderstanding, it might be well to set forth certain definitions. The word "Cathodic" refers to or is related to the word "cathode," which is a fundamental part of an electric cell. In fact the speaker believes this treatise can be better understood if we consider the tank and associated parts, which we will describe, as a large electric cell. Now, a cathode is defined in electro-chemistry as that pole or electrode in an electrical wef cell toward which the electricity flows through the liquid in the cell, the latter being designated the electrolyte. It is the electrode by which the electric current leaves the cell. In our case the cathode is the tank body itself, and of course it is this cathode that we wish to protect. (Incidentally the electrode by which the electricity enters the electrolyte is called the anode.)

The word "protection" immediately gives rise to the question, "Protection against what?" The answer is protection against corrosion, which is basically electro-chemical in the final analysis, as will later develop.

It then becomes necessary to define corrosion. We could spend several minutes, even perhaps hours, on this one subject. Mr. U. R. Evans in "The Corrosion of Metals" has given a definition of corrosion in very few words; and is, I believe, quite to the point. He says that while the study of metallurgy is the study of "making of metals," a study of corrosion is a study of the "unmaking of metals." In other words, corrosion is the process of the return of metals to their native state. In the case of steel or iron this is the oxide or the hydrous oxide.

As to the term "Water Tanks," of course we all know what a water tank is. Nevertheless, in order to narrow this paper down to its precise application, we well define a water tank for the purpose of this paper as a steel or iron tank. Tanks of concrete and non-ferrous metals will not be considered in this paper.

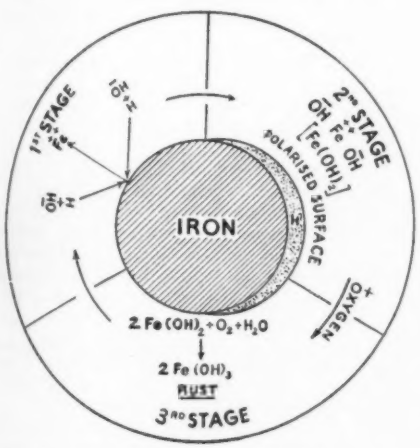

Fig. 1. The Progress of Corrosion and Rusting, Graphically Pictured.

The 1st stage is that of solution and ionization of the iron in which small D. C. current flow is produced—such flow being subject to reversal by opposing current input. The 3rd stage is that of oxidation by dissolved oxygen and visible rusting. Rust is the return of metallic iron to its native state, the oxide, and is in reality nature's "scab" that forms over the "sores" of corrosion.

Theory of Corrosion

We could spend a lot of time going into the theories of corrosion. These theories involving as they do, not only Ohms Law, Faradays Law and Electrolysis, but also atoms, ions, electrons and a lot of other "ons" are liable to get one into "deep water," particularly one whose knowledge on some of these things is as limited as is your speaker's. After all, I believe we are not so interested in theory, but are very much interested in exactly what happens. Therefore, I am going to pass over the theory and go immediately to the problem of what happens in such situations.

The progress of corrosion of iron and the three stages from metallic iron to rust or tubercles is rather effectively pictured in the accompanying graphical sketch of the corrosion cycle.

Practice

We are all more or less familiar with ordinary electro-plating processes. For example, in case of copper plating, an article is placed in a copper solution and an electrode of pure copper (the anode) is also placed in the solution. A direct current enters the cell by means of this anode and passes through the copper solution (electrolite) and onto the article which is to be plated. The article is the cathode and receives the copper transported by the flow of introduced current. In this process the anode passes into solution at a rate determined by the direct current input.

Another example is familiar to all of you who have ever operated a water system in a city blessed with street cars. You of course are familiar with the fact that the destruction of water mains by electrolysis occurs only at points at which electricity *leaves* the main. At such points the water main is an anode. On the other hand, at places where the electric current goes onto the mains no damage is done.

These two very familiar examples are given simply to refresh our memories because these two examples are but examples of the same process in which we are interested in this discussion.

Application

Although one would think by the large number of inquiries on the subject of cathodic protection of water tanks this must be a brand new invention, such is not the case. The same basic idea has been used on pipe lines for many years, the first application having been made in about 1930. In the case of pipe the protection is against external corrosion (soil pitting) and not internal as is the case with water tanks.

While there are many installations of pipe lines protected by the cathodic method of corrosion control, the two that I will now mention will serve as examples.

A pipe line of interest is one in Louisiana about 80 miles long. A five-mile section was especially studied for purposes of determining the effectiveness of electrical protection. On this five-mile section during the six months immediately preceding the application of the protection an average of 5.5 pit leaks per mile per year developed. It was not anticipated that the application of cathodic corrosion control would immediately reduce the leaks.

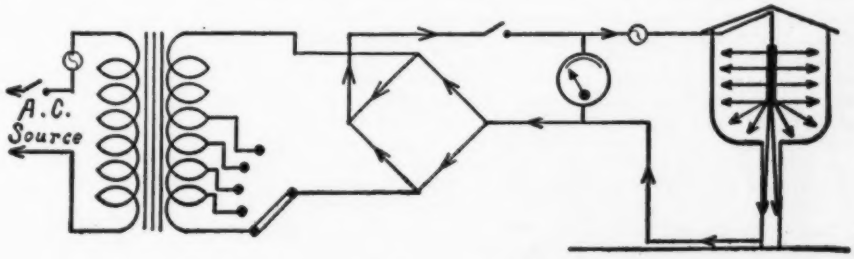

Fig. 2. A Schematic Sketch of Cathodic Protection.

This "flow sheet" indicates the conversion of A. C. to D. C. current in passing through the rectifier (left); flow as D. C. through the suspended anode in the tank (right) and its travel radially through the electrolyte (water) as a plating current to the cathode (tank walls). The ions of hydrogen and metals in general (notably calcium) are plated out on the tank surface or on any other submerged metallic surface which has a conducive ground connection.

In fact, it was thought that perhaps the number of leaks might actually increase for a time after the process was started. This was found to be the case, for during the six months immediately following the application of cathodic corrosion control, an average of 8.8 leaks per mile per year developed. The theory is that the cathodic corrosion control removed some of the accumulations of rust from the pits which were already badly developed, and so weakened the pipe wall that additional leaks actually showed up. During the next twelve months, however, the average number of leaks dropped to 0.2 leaks per mile per year. After the system had become thoroughly established and in operation beyond any question of doubt, the protection was shut off to see what would happen. During this first six months, it was expected that the number of leaks would not be serious. This was found to be the case because only an average of 0.8 leaks per mile per year developed. The cathodic corrosion control was, therefore, placed back in operation immediately and the leaks tapered off to practically zero again.

Another interesting installation was the application of cathodic corrosion control to the pipe lines of Treasure Island at the World's Fair in San Francisco. This installation and results are presented in a detailed account by Mr. Charles E. Lee in the A.W.W.A. Journal of February, 1940. These pipe lines are laid through "made" ground, which is extremely corrosive. The first failure occurred ninety days after the pipe was placed in service. During the next seven weeks forty-eight failures occurred. Thereupon cathodic corrosion control was applied to all underground pipe structures on Treasure Island with results quite comparable to those indicated previously for the pipe line in Louisiana. The World's Fair authorities estimated that if no cathodic corrosion control had been applied 518 leaks would have developed during the thirty weeks of construction previous to opening the Fair, rather than the actual number of 146 leaks, and most of these 146 leaks occurred before the application of the inhibiting process.

Application to Tanks

The application of cathodic corrosion control to tanks is in theory quite like the application of cathodic corrosion control to pipe lines except that in the case of tanks the aim is to protect the container against internal corrosion, that is, corrosion from the water itself, while in the case of the pipe lines the aim is to protect the container against external soil corrosion. Therefore the application of cathodic corrosion control in tanks should be a much simpler process, and subject to more exact observations and adjustment if required.

Although I indicated a few minutes ago that I would pass by the theory, I think it would be well to reconsider very briefly just a little theory involved in the application of this method of control of corrosion in tanks. If we set up a cell consisting of a suitable anode in water, in a tank, and if we then circulate direct current of a suitable voltage and amperage from the source of supply into the anode, thence to the water and on to the tank, a plating action will take place quite similar to that described previously relative to electro-plating processes. Instead of plating out copper, silver or some other metal, however, in this case hydrogen gas in the form of hydrogen ions will plate out onto the surface of the cathode the tank walls. Calcium and other positive ions (depending upon the mineral content of the water) will also plate out against the surface of the tank in the same manner. As long as this process is kept up, and as long as the film of hydrogen, calcium, etc., remains unbroken, rusting and other forms of corrosion on the tank surface will not take place.

It is therefore only necessary to provide the equipment to keep this process in operation. In practice, this consists of one or more electrodes of a suitable material (usually either stainless steel or graphite) suspended from the roof of the tank into the water, but insulated from the tank. These are the anodes. There is also provided a source of current supply. This usually consists of a transformer, a dry type of rectifier and suitable controls so that the voltage and current can be adjusted to the needs of the particular installation. What determines the current required is the mineral content of the water and distance between the anode and the tank walls; also to what extent the original protective coating on the tank interior has disappeared. In the case of very badly corroded tanks the current flow may be considerable in the beginning until the protective film has deposited sufficiently to retard current flow.

These devices are connected so direct current from the rectifier runs from the rectifier to the anode through the water onto the tank, thence back to the rectifier. (See flow diagram.)

Comporative Costs Important Consideration

No matter how unique or interesting a piece of apparatus might be, it can hardly be justified unless economy is shown by its use. If capital investment is necessary, the fixed charges incurred by such capital investment must be considered. If operating costs are incurred, these must also be considered. In the case of cathodic corrosion control, both of these costs are incurred. The capital cost, when once invested, however, is not repeated year after year. And, strangely enough, in many cases the capital cost of cathodic corrosion control equipment is less than a single paint job. The operation costs are also very nominal. The equipment consumes so little power each month that in many cases the power cost is within the minimum charge for the use of electric service.

In one case (a 350,000 gallon tank) the cost of painting the interior of the tank below the water line would have been $700.00, while the capital cost of cathodic corrosion control was only in the neighborhood of $400.00. In like manner, a certain 750,000 gallon tank was equipped with cathodic corrosion control equipment at a cost of a little over $400.00, whereas the cost of painting the inside surface of that tank below the water line would have been $950.00. In the case of this 750,000 gallon tank, assuming a paint job to last five years, would make the cost of paint $190.00 per year. If we assume a fixed charge to cover taxes, depreciation and maintenance on the cathodic control unit at fifteen per cent, we have a fixed charge of $60.00 per year, to which must be added the charge for electric service amounting to $12.00 per year, or a total cost of $72.00 per year. This leaves an annual profit of $118.00 per year or 29.5 per cent on the investment.

Convenience Also a Consideration

This financial saving or profit is not the only advantage, however. We should also keep in mind that we are: (a) preventing the tank itself from disintegrating, which after all is even more important than the financial savings, and (b) making it unnecessary to take the tank out of service for periodic painting. Since painting must be done during the warmer months, when the tank is most needed in service, the matter of removing a tank from such service is oftentimes a serious problem, and is the most prevalent reason for deficient tank maintenance.

Conclusion

In conclusion let me repeat that cathodic corrosion control is not new. It is a very old principle. In fact, it is very strange, in the writer's opinion, that it has not been applied many years ago. However, there are approximately 600 water tanks in the United States at the present time to which this treatment has been applied.

Replies to a questionnaire, circulated by the Pittsburgh-Des Moines Steel Company, indicate an overwhelming majority in favor of cathodic corrosion control. Replying to the question, "Does the electric rust prevention device protect the tank interior as well as paint or other coating material?" sixty-eight per cent said, "Yes," seventeen per cent did not answer the question, eight per cent could not say, but nobody replied in the negative. As a matter of fact, the purveyors of cathodic protection equipment guarantee that the answer is—"Yes."

In response to the question, "If you were building a new water tank, would you specify that the paint be omitted on the interior below the water line?" seventy-five per cent replied "Yes," twenty-five per cent did not answer the question, but nobody replied in the negative. This questionnaire revealed that the original capital cost of the equipment ranged from $198.00 to $525.00, while likewise the annual maintenance cost ranged from $3.00 per year to $25.00 per year. It is apparent that the answer to the current cost is this—the more the tank is in need of protection the greater the current costs in the early period of application. The less the corrosivity of the water, or the better the condition of the original protective coating, the lower the current requirement and operating costs.

There is no question but that the water works industry has been presented with a very useful and inexpensive device. There is no question as to its economy and, if the electrodes are mounted in such a manner as to preclude difficulty from freezing, it is the writer's opinion that this device will receive the wholehearted support of the water works industry and enjoy nation-wide adaptation.

In closing, I wish to extend my thanks and appreciation to the many individuals and organizations who have rendered valuable assistance in the preparation of this paper.

Acknowledgment—This article is, for the most part, portions from a paper presented by Mr. Norman before the 1940 *Convention of the American Water Works Association. The sketches are those illustrating an article on "Cathodic Protection," by Wm. D. Loreaux, which was reproduced in the Reference and Data Number of "Water Works and Sewerage" for* 1940*—Ed.*

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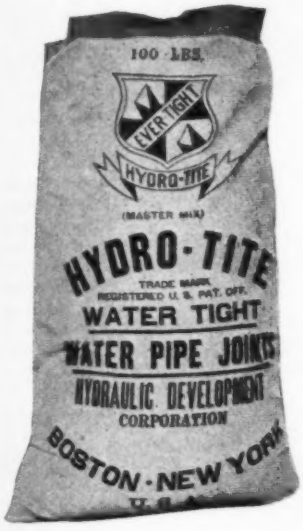
OTHER PRODUCTS — Wood Burning Furnaces, Pouring Pots, Pouring Ladles, Yarning Irons, Joint Cutters, Joint Runners, Open Seam Pouring Funnels.



Properties of HYDRO-TITE

HYDRO-TITE is a black powder composed of selected inert minerals. When melted and allowed to cool, it becomes a strong, tough, metallic mass. Compressive strength is 6,000 lbs. per square inch and its tensile strength is over 650 lbs. per square inch.

Manufacture of HYDRO-TITE

HYDRO-TITE is made in an up-to-date factory with modern machines and by efficient methods. Constant inspection, alert supervision and many years of research by some of the best trained chemical scientists combine to make HYDRO-TITE the leader in its field. This makes possible our continued use of the slogan—"MORE THAN 30 YEARS WITHOUT A FAILURE."

HYDRO-TITE Features

Self-Caulking: HYDRO-TITE is melted by a small fire and nothing is added to make it liquid. When poured into a joint it immediately solidifies upon contact with the metal and bonds to both the surface of the bell and the spigot for the entire length of the joint. HYDRO-TITE requires no caulking.

Self-Sealing: HYDRO-TITE joints are, under normal conditions, perfectly tight when pressure is first applied. Any leak or seep from a new joint will soon be stopped by the self-sealing quality of HYDRO-TITE. Even leaks occurring when pouring over-heated HYDRO-TITE will seal themselves within a day or two. "Less leakage from the start and quicker sealing qualities in case of small leakage."

Ready for Immediate Use: There need be no waiting time after pouring a joint with HYDRO-TITE. It solidifies at once upon contact with the pipe and is ready for regular pipe service.

RESISTS VIBRATION: HYDRO-TITE can be used anywhere. It is in service on pipe lines carried over bridges subjected to heavy automobile trucking, trolley cars and continuous railway traffic.

DRY BRAIDED FIBREX

A Sanitary Packing used in Jointing Bell and Spigot Pipe for Water Mains—Sewer Mains—Soil Pipe.

FIBREX is the answer to the constant demand by Sanitary Engineers for a packing which will not breed bacteria when used in water mains. Fibrex is a paper packing treated with a special water repellent which keeps the Fibrex sterile and prevents it from disintegrating. It has a hard twisted core with a basket weave covering and packs in a joint exactly the same as braided jute.

FIBREX is 30% lighter in weight than dry braided jute and is put up in 60-pound reels. Each reel will take the place of over 90 pounds of braided jute and the cost per pound is approximately the same for both Fibrex and jute. This effects a 30% saving in cost.

FIBREX was designed for use with Hydro-Tite and other self-caulking compounds. However, it is entirely suitable for joints made with lead, also for Sani-Tite and other asphalt sewer joint compounds.

Thousands of pounds of dry braided Fibrex are already in service on water lines throughout the country. It has the approval of the War Department at Washington, several different Area Engineer Offices of the War Department, the Departments of Public Health in some of our larger states and numerous Water Departments.

Laboratory tests have been made by Skinner & Sherman, Inc., Chemists and Engineers, Boston, Mass., and their report shows that Fibrex does not breed bacteria, as is characteristic of jute, in both sterile and contaminated water.

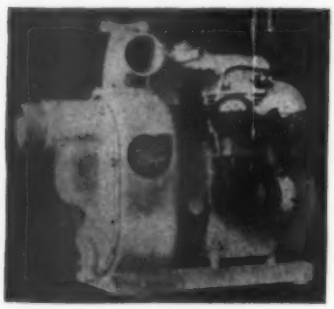
FIBREX is made in ⅜", ½" and ⅝" sizes The ½" size is used on nearly all joints. The ⅜" and ⅝" sizes are used on thick or thin joints, as in case of some specials or changing over from one class pipe to another.

NORTHROP & COMPANY, INC.

Water Works Specialties and Supplies

50 Church Street • NEW YORK, N. Y.

Marlow Lightweight, Self-Priming Centrifugal Pumps 3,000, 7,000 and 12,000 G.P.H.



1½", 2" and 3" sizes weighing respectively 60*, 100, and 106 lbs. (*76 lbs. with cast iron pump). Easily carried by one or two men. 25 foot vertical suction lift and will discharge against a total head of 55 ft. Powered by four cycle, air-cooled gasoline engines equipped with magneto ignition, speed changer and tapered roller bearings on crankshaft.

The pump shell is self-cleaning with open type impeller specially adapted for dirty water. A special long-wearing shaft seal replaces packing.

The NEW AQUA-MAGNETIC VALVE-BOX LOCATOR

A sensational new type magnetic valve-box locator now being used by waterworks and utilities companies all over the country. Makes child's play out of locating lost and buried valves and shut-offs. Can be read from standing or walking position, as it is carried along in genuine leather carrying case with shoulder strap . . . no stooping or kneeling.

Genuine 35% cobalt alloy steel needle, air-dampened to eliminate flywheel action . . . sapphire jewel bearings . . . gum rubber mountings to protect needle from jolts that tend to demagnetize needle . . . accurate, sensitive compass. Case has chrome-nickel handle for use under shrubbery, etc. Sent out on free 15-day trial.

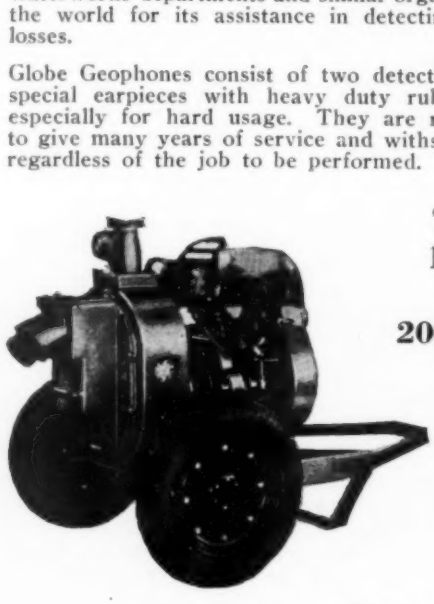
The GEOPHONE LEAK LOCATOR

Leaks are found quickly — excavating eliminated —large losses avoided — when using the internationally acclaimed Globe Geophone!

Operating on the principle of the Seismograph — the instrument used for detecting earthquakes —the Geophone enables the accurate location of underground leaks—water, steam or gas—within a radius of inches! "Unaccounted for" losses—leaks that do not show on the surface—are quickly apprehended by a Geophone survey.

Originally developed during World War I for detecting enemy sapping and underground mining operations, the Geophone is considered the "right-hand man" of hundreds of waterworks departments and similar organizations throughout the world for its assistance in detecting leaks and saving losses.

Globe Geophones consist of two detecting units coupled to special earpieces with heavy duty rubber tubes designed especially for hard usage. They are ruggedly constructed to give many years of service and withstand extreme abuse, regardless of the job to be performed.



Two Wheel Mounted— 7,000 to 200,000 G.P.H.

2" to 10" Marlow gasoline engine powered units are mounted upon pneumatic or steel tired trailer carts.

Pumps are equipped with trash type impellers, self-cleaning casings and special long-wearing shaft seals. Special feature allows removal of trash accumulated in the suction housing through hand hole plate without stopping engine or losing priming water. Automatic control device prevents re-circulation of water after pump is primed.

Also complete line of Marlow Diaphragm and Plunger pumps. Immediate shipment with proper priorities.

OTHER PRODUCTS:

Portable Compressors, Stationary Compressors, Pneumatic Tools, Thawing Generators, The "Flow-O-Meter", Leak Locators, Pipe Finders, The Meter-Master, Air Valves, Pipe Cutters, Pipe Pushers, Repair Couplings, Steam Thawers, Gauge Testers, Meter Boxes and Yokes, Valve and Curb Boxes, Meter Testers, Meter Seals and Books, Lanterns and Torches, Slide Comparators, Water Analyzer, Color Standards.

HYDRANT DISCHARGE MEASUREMENTS

Practical Methods of Making Measurements; Computing and Applying Results

By P. S. WILSON
Water Works Consultant, Glen Ridge, N. J.

The measurement of the discharge or flow from fire hydrants is a common procedure for engineers engaged in testing the fire fighting capacity of a water system. The fact is frequently overlooked that such measurements may also be very usefully applied to many other vital problems with which the operator of a water supply system is regularly confronted. It is likewise not always realized that this work may be performed with but a small expense for equipment and without the need for special technical training.

Actual measurements of the flows taking place in a water distribution system may furnish extremely valuable information to the water works operators. A water distribution system is different from most of the equipment with which other business is conducted. It is buried underground and is not subject to ready inspection. The greater portion of it has not been seen for a generation or more. Its present operator has never seen most of it and almost all he knows of it is what he has been told second or third hand or what he learns from maps and records which are in many cases woefully deficient. What information he does obtain about his system is mostly history,—what it was when it was last seen, years before, not what it is now. It is on account of these conditions that actual tests and measurements are of such great value. One can authorize for a long time as to whether a certain valve is open or shut and one may even operate the valve one way or another and still not know much more than before. But if the water in proper quantity flows through that valve and evidences itself on the other side, then the question is settled and there is no more possibility for argument.

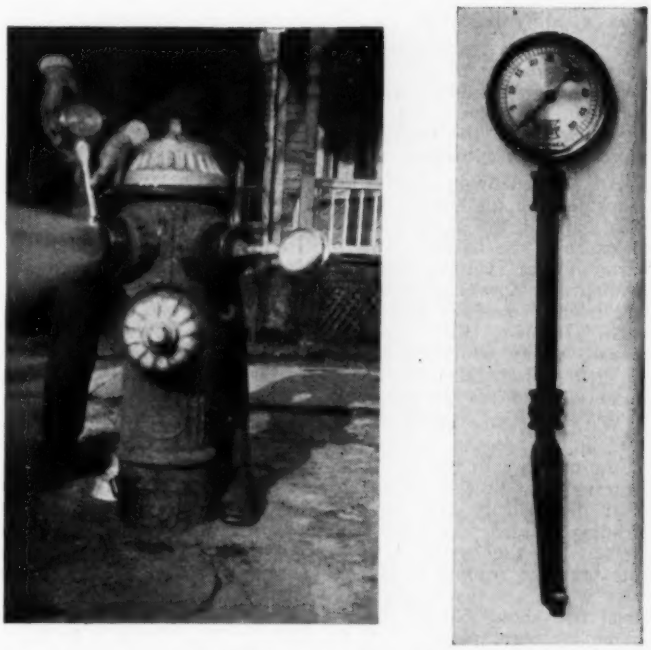
There are two principal methods of making field measurements of the flows in water distribution systems. One of these is by means of the Pitot orifice tube inserted through a corporation cock in the side of a main. Such measurements when properly applied are of inestimable value. However, a method, of making tests, which is more readily available to the average operator, involves the measurement of hydrant discharges and less time, expense, and equipment are necessary therefore. Measurements so made are not, of course, a complete substitute for Pitot measurements in the pipes, but in many cases they may suffice in themselves to answer the questions at hand. Even if they do not, they always form a valuable guide and adjunct in the making of further and more elaborate tests, if these are later found necessary.

Methods of Measuring Hydrant Discharge

Measurements of the discharge from an ordinary fire hydrant with sufficient accuracy for most practical purposes is not difficult. By the exercise of care and good judgment, results may be obtained within fairly close limits of accuracy. Rough and ready methods are for the most part amply sufficient, since, for the purposes usually involved, the conclusions arrived at would not be changed by a variation of five or ten per cent one way or the other in the test results. Some of the rather approximate methods to be given must be judged with this fact in mind.

The discharge from a hydrant nozzle is determined from the size or cross sectional area of the emerging stream and from the average velocity of that stream. From these two figures the discharge may readily be computed or may be directly read from tables or diagrams such as those appended to this article.

Measuring Nozzle Diameter—Observation of flow from hydrant nozzles shows that it completely fills the nozzle, as a general rule. Therefore, a simple measurement of the internal diameter of the hydrant nozzle serves to make known the diameter of the stream of water. The entrance to the nozzle from within the barrel may occasionally (particularly in some old styles of hydrants, and hydrants with independently gated nozzles) be sharp enough to cause the emerging stream to be contracted slightly below the size of the nozzle and if such an effect is noted it should be allowed for in the diameter used. The internal diameter of each nozzle used should be carefully measured to the nearest one-sixteenth of an inch. An ordinary carpenter's rule is satisfactory for this purpose.



Two Methods of Determining Velocity of Nozzle Discharge. (Gage on Pitot Tube Held in Stream and Gage, Indicating Barrel Pressure, Show Practically Same Readings)
Hydrant Pitot Tube with Gage at Right

Determining Stream Velocity—The average velocity of the emerging stream of water may be determined in either of two ways. The most common method is by the use of a hydrant Pitot tube which may be inserted into the stream and which transforms the velocity head of the stream into the equivalent pressure head and registers it on an attached pressure gage. This instrument is here pictured. It consists of a hollow blade or "cut-water," shaped so that it may be thrust into the stream without unduly deflecting it. At the end of the blade is a small opening which points directly against the flowing water. The force of the stream striking into this opening creates a pressure in it which is transmitted through the hollow blade and handle to the pressure gage. The gage is an ordinary good pressure gage, except that it should be graduated to read more closely than most gages. The gage most frequently used is graduated every pound and only reads up to about fifty pounds per square inch pressure. It must be a good grade of gage to maintain its accuracy with such close reading. For some purposes it is of value to have a very low pressure gage graduated to half pounds. Sometimes the Pitot tube and the gage are held in place in the stream by a device which clamps over the outside of the nozzle. This device is not ordinarily considered necessary, however, and its use results in greater damage to the Pitot tube if struck by a stone or other object carried by the water. The edges of the blade and the small orifice into it must be kept sharp and symmetrically shaped or the accuracy of the instrument will be seriously affected.

In use, the Pitot tube is held in the stream and the pressure read while the small orifice is held at the center of the stream and pointing directly against the flow. Occasionally on large nozzles it is advisable to take a rough average of the pressures across the stream at different points horizontally and vertically. In most cases the pressure at the center will be found to be practically the average. In no case should the pressure very near the edge (within about one-fourth inch) be considered.

The other method of determining the velocity of the stream, and one which has been occasionally found more convenient by the writer, consists merely in placing on one of the hydrant nozzles a cap having an ordinary pressure gage tapped into it then allow the discharge to take place through the other nozzles. Due to the free discharge from the nozzles, practically all of the pressure head remaining in the barrel during the flow is transformed into velocity head in the jets. Since that is practically the only source of velocity head in the jets, the ordinary pressure gage indicating the pressure in the barrel will read substantially the same as a gage on a Pitot tube held in a jet. This fact may be readily confirmed by trial. In this way the discharge of a hydrant may be measured with fair accuracy, without the Pitot tube, merely by the use of a pressure gage, the gage reading being used to compute the discharge in the same manner as if it were a Pitot tube reading. The same type of gage should be used for this method as described above for the Pitot tube. Any pressure gage may be used, however, the accuracy of the results depending upon the accuracy of the gage and the closeness of the graduations and readings.

An accompanying illustration shows a Pitot tube with gage being held in the stream from one hydrant nozzle while a pressure gage on the other nozzle is at the same time indicating the pressure in the barrel. This illustrates the two methods of determining the velocity head of the stream. Unfortunately the photograph does not make it possible to see what the gages are reading; actually they show the same—18 pounds per square inch. In using the Pitot at low velocities, where a quarter pound makes an appreciable difference, the instrument should be held horizontally so that the pressure gage will be at the same elevation as the nozzle.

With the same accuracy of gage reading the only inaccuracies in the second method as compared with the use of the Pitot tube are in the fact that there is a slight loss of head in entering and flowing through the nozzle and in the assumption that the velocity head in the barrel at the point of pressure reading is zero. This latter assumption is justified because the velocity in the barrel is low compared to that in the jet and the pressure reading is taken opposite or above the other nozzles which are discharging. In any case, as before mentioned, trial will show that the results are in general substantially the same for both methods. If the hydrant Pitot tube is at hand, its use is best and most convenient; the availability of the other method, however, should always be borne in mind.

The pressure gage on one nozzle, of course, prevents the use of that nozzle for the discharge of water. This is not always a disadvantage, however, particularly when the hydrant is equipped with a steamer nozzle which may be used for attaching the gage.

A fact which may readily be perceived from the foregoing is that, when measuring the velocity with a Pitot tube, readings need only be taken (except as a check) in one of several nozzles discharging simultaneously because readings in all of the nozzle streams should be practically alike.

Computation of the Flow

By the measurement of the nozzle diameter we now have obtained a diameter of the stream of water, and from the pressure gage reading we have obtained a figure which bears a known relation to the velocity of the stream. The formula for the discharge may now be readily derived from the fact that:

Discharge = (area of stream) × (average velocity)

If d = the internal diameter of the hydrant nozzle in inches, then, using the formula for the area of a circle, the area of the stream is $\frac{3.14xd^2}{4}$ square inches. For convenience in computing, this is divided by 144—the resulting formula being $0.00545xd^2$ to obtain the area of the stream in square feet.

The pressure gage reading, in pounds per square inch (p) is changed to feet of water head by multiplying it by 2.31. A fundamental hydraulic formula states that the velocity of the stream of water is equal to the square root of the pressure head multiplied by the square root of two times the acceleration of a falling body, due to gravity. This latter (g) is a constant and is equal to 32.2 in foot and second units. Therefore:

(a) Velocity of the stream in feet per second =
$$\sqrt{2.31 \times p} \times \sqrt{2 \times 32.2} = 12.2 \times \sqrt{p}$$

(b) Discharge in cubic feet per second =
$$0.00545 \times d^2 \times 12.2 \times \sqrt{p} = 0.0665 \times d^2 \times \sqrt{p}$$

(c) Discharge in gallons per minute =
$$29.9 \times d^2 \times \sqrt{p}$$

The velocity of the stream of water as determined by either of the two methods described does not take into account the very low velocity of the stream around the edges where it is held back by its contact (friction) with the nozzle. To make allowance for this, as well as to allow for a possible slight contraction of the jet, it is necessary to make use of a coefficient in computing the results. This coefficient has been determined experimentally by checking hydrant flow measurements against other and more accurate means of metering the flow. The coefficient should, theoretically, be different for different hydrants, but it is sufficiently accurate for the purposes and means of measurement under discussion to use an average figure which has been found by experiment to be about correct for most cases. The figure most generally used is 0.90 and thus the formula derived above is modified as follows:

(d) Discharge in gallons per minute =
$$0.90 \times 29.9 \times d^2 \times \sqrt{p} = 26.9 \times d^2 \times \sqrt{p}$$

For convenience the 26.9 may be rounded off to an even 27 without introducing an error of importance, resulting in the completed formula:

(e) Discharge in gallons per minute =
$$27 \times d^2 \times \sqrt{p}$$

in which d = diameter of nozzle in inches and, p = gage reading in lbs. per sq. inch.

The Advantage of Tables and Charts

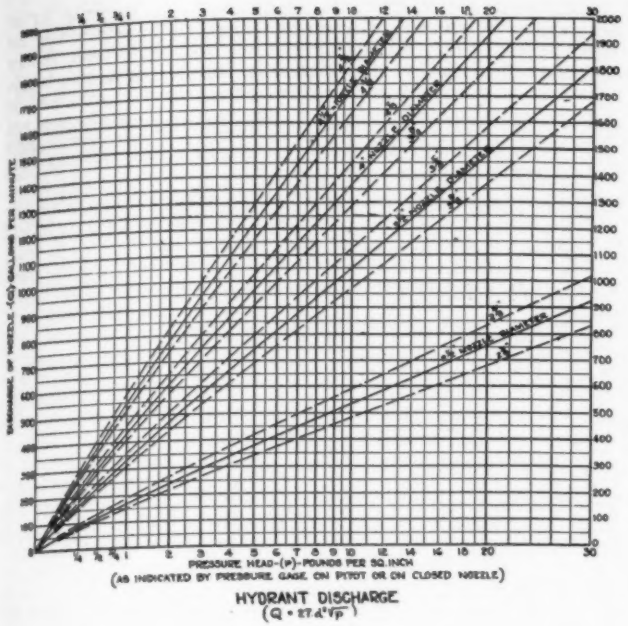
From this formula tables may be constructed in which the discharge is given for each combination of diameter of nozzle and Pitot pressure head and from which the result of the measurement may therefore be read directly without computation. A specimen is shown in Table 1. The discharges in this table are given to the nearest ten gallons per minute. Tables may be made up very conveniently to fit in field note books. For special purposes they may be abbreviated or enlarged either in range or in closeness of reading.

Another method of handling the formula is by the use of diagrams. A particularly convenient form for such a diagram, which the author has never seen in use elsewhere, accompanies this article. In this diagram measurements horizontally from the origin or zero are proportional to the square root of the Pitot pressure head, $\sqrt{p}$. Measurements vertically are proportional to the discharge of the hydrant nozzle in gallons per minute. An inclined straight line passing through the origin then represents each value of the nozzle diameter, (d). A heavy line is drawn for each size of nozzle in use using the theoretically correct value of d,—for example 2½ inches for an ordinary hose nozzle. Light lines are then drawn on the diagram below and above the first ones representing ⅛-inch undersize and oversize of each nozzle. From these three lines values for each 1/16 to ¼-inch under and over the nominal sizes may readily be read on the

TABLE 1—HYDRANT DISCHARGE*
Gallons per minute = 27 $d^2 \sqrt{p}$

Gage Reading—Hoze nozzle diameter in inches [d]						
p	2	2⅛	2¼	2½	2¾	3
¼	70	80	80	80	90	90
½	100	110	110	120	120	130
¾	120	130	140	150	150	160
1	140	150	160	170	180	190
1¼	160	170	180	190	200	210
1½	180	190	200	210	220	230
1¾	190	200	210	220	230	250
2	200	210	230	240	250	260
2½	230	240	250	270	280	290
3	250	260	280	290	310	320
3½	270	280	300	320	330	350
4	290	300	320	340	350	370
4½	310	320	340	360	380	390
5	320	340	360	380	400	420
5½	340	360	380	400	420	440
6	350	370	390	410	430	460
6½	370	390	410	430	450	470
7	380	400	420	450	470	490
7½	400	420	440	460	490	510
8	410	430	450	480	500	530
8½	420	440	470	490	520	540
9	430	460	480	510	530	560
9½	440	470	490	520	550	570
10	460	480	510	530	560	590
11	480	510	530	560	590	620
12	500	530	560	590	610	650
13	520	550	580	610	640	670
14	540	570	600	630	660	700
15	560	590	620	650	690	720
16	580	610	640	670	710	740
17	600	630	660	700	730	770
18	610	650	680	720	750	790
19	630	660	700	700	770	810
20	640	680	720	750	790	830
22	680	710	750	790	830	870
24	710	750	790	830	870	910
26	740	780	820	860	900	950
28	760	810	850	890	940	980
30	790	830	880	920	970	1020

*Discharges shown to nearest 10 gals. per min.



Hydrant Discharge Diagram. (Courtesy, Community Water Service Co.; this Chart Having Been Prepared by the Author While Connected with the Company)

diagram. This covers the usual variation of the nozzles. It is to be noted that the horizontal distances on the diagram are not directly proportional to the pressures but to the square roots of the pressures. This results in uneven spacing of the figures, but by so constructing the diagram the lines representing the nozzle diameters may be drawn straight, whereas otherwise they would be curved. The uneven spacing of the pressure lines makes accurate interpolation difficult, and therefore enough lines are drawn on the diagram to make this unnecessary. Having made a discharge measurement this diagram is used as follows: Pick the vertical line representing the Pitot pressure reading, follow it up or down to where it crosses the line representing the actual measured internal diameter of the nozzle, estimating where that line would be if the correct one is not on the diagram. Then follow the horizontal lines to right or left and read the discharge on the vertical scale.

A Few Comments

A careful study of the formula and the tables and diagrams leads to a number of important observations on the carrying on of this work. When the Pitot pressure reading is low, a slight difference in the reading will result in a very large percentage difference in the result, whereas at higher pressures a half pound or even a pound does not make much difference. For instance the difference between 1 and 2 pounds per square inch makes about 40 per cent difference in the discharge while the difference between 10 and 11 pounds per square inch makes only about 5 per cent difference. This fact is the reason for making the pressure differences in the table and diagram smaller in the lower range. It also indicates the necessity for making very careful Pitot pressure determinations in the field, particularly at low pressures. Gages should be closely graduated as before mentioned and should have at least three inch dials. On particular work they should be calibrated with a dead weight tester before and after using and corrections applied to the readings if necessary. Gages should be handled gently and with care so as to maintain their accuracy. Since they will probably not read as high as the static pressure in the mains, care should be taken when taking pressures on a closed nozzle not to subject them to too much pressure. Other gages must, of course, be provided for taking the direct main pressures.

Emphasis must be placed on the necessity for keeping the connections between the Pitot blade and the pressure gage absolutely tight. A very slight leak, in fact only a drip which in the general splashing may not be noticed, is sufficient to make the reading considerably in error. The connections should be made up tightly with wrenches and should not be loosened in order to turn the gage into a more convenient position.

It will be noted that a 1/16-inch difference in the diameter of the nozzle makes a much greater percentage difference at high discharges than at low ones. This is the opposite from the effect of the pressures. In spite of this it will usually result in greater accuracy to use as few and as small nozzles as possible in a measurement. The use of steamer nozzles is advised only on work where approximate results would be satisfactory. Further experiments may show that a slightly different coefficient should be used in computing the discharge of the larger sizes of nozzles.

Fire Flow Tests

The making of fire flow tests is the most obvious use to which hydrant flow measurements may be put. Such tests consist in the determination of what amount of water is available at a given hydrant, or at a given group of hydrants, for use by the fire department. This test is the one usually made by the engineers of the National Board of Fire Underwriters in rating a system for fire protection. So much has been written on such tests that they need be only mentioned here. Simultaneous readings are taken on as many hydrants in a group as are needed in order to develop the capacity of the system. At the same time a record is kept at an adjacent hydrant (not discharging), of the residual pressure. From a set of such readings the discharge capacity of the system at that point with any residual pressure may be known.

The residual pressure mentioned above is the pressure remaining in the mains during the time that a flow test is taking place. This pressure is determined by the readings of a pressure gage attached to a hydrant which is *not* discharging but which is located close by and, if possible, on the side opposite to the direction from which the flow is coming. The actual capacity of the distribution system at a given point is usually considered to be the discharge with the residual pressure drawn down to some stated figure. By this method the results of flow tests at different points and on different systems are made comparable. When fire engine pumpers are to be used then the maximum capacity of the system may be considered as the discharge with the residual pressure drawn down to 20 lbs. per sq. in. If reliance is placed on direct hydrant pressure for the hose streams then the residual pressure can not be drawn down nearly so low and the maximum capacity of the system at such higher residual pressures will be less. Sometimes the capacity of a system is referred to as the discharge with a drop in pressure of 20 lbs. per sq. in., in other words, with a residual pressure 20 lbs. per sq. in. less than the original pressure before the hydrants were opened. This will usually be a very different figure from the capacity at 20 lbs. per sq. in. minimum residual pressure.

It is usually difficult or impossible to make a flow measurement at exactly the rate of discharge which will result in the residual pressure desired. It is customary, therefore, to make the measurement at some rate of discharge as near as convenient to that producing the effect desired and then to compute what the discharge would have been at the residual pressure desired. This may be done by applying the fact that the discharge is approximately proportional to the square root of the drop in pressure.

If, for example, the original pressure in the mains before opening the hydrants had been 56 lbs. per sq. in., and the residual pressure during a flow of 2680 gallons per minute had been 32 lbs. per sq. in., then the drop in pressure during that flow was 24 lbs. per sq. in. Suppose now that it were desired to know in this example what the discharge would have been with a residual pressure of 20 lbs. per sq. in. The drop in pressure in that case would have been 36 lbs. per sq. in. It is then merely necessary to multiply the measured discharge (2680 gal. per min.) by the square root of 36 (which is 6.0) and divide by the square root of 24 (which is 4.9).

$$\frac{2680 \times 6.0}{4.9} = 3280$$ gal. per min. which would have been the discharge at 20 lbs. per sq. in. residual pressure.

If Q_1, is the measured discharge with a drop in pressure of D_1; and, Q_2 is the discharge which would have taken place with a drop in pressure of D_2 then the above method may be stated in a general formula as follows:

$$Q_2 = Q_1 \times \frac{\sqrt{D_2}}{\sqrt{D_1}}$$

This method, as stated before, is only approximate and it should not be considered very reliable if the drop in pressure at the measured discharge is very greatly different from the drop in pressure desired. The method is, however, entirely satisfactory for most practical purposes.

Fire flow tests may indicate not only whether the system has the desired capacity or not, but they may be amplified to give

information as to what work should be done to increase the capacity. For example, by taking a record of the pressures in the system during the flow test at various points progressing back toward the source of supply, it may be conclusively shown whether a restriction is in the principal supply mains or whether it is in the local mains adjacent to the test. By cutting out certain mains during the test still further information may be gained as to the actual conditions existing; closed valves or other obstructions, defective hydrants, or large leaks may be discovered and located. This work opens up a great field for the display of ingenuity on the part of the operator since the exact procedure is subject to unlimited variation and depends upon the arrangement of the particular system under test.

For further details and information regarding fire flow tests the reader is referred to a paper published in the *Journal of the American Water Works Association*, Volume 12, No. 2, October, 1924, by Mr. George W. Booth.

Other Uses for Hydrant Flow Measurements

There are many other varieties of tests, measurements and experiments which may be performed on a distribution system through the use of hydrant discharge measurements. They may be used in making determinations of the friction coefficient in certain mains of the system. By isolating a stretch of pipe so that the feed into it is from one end only, a flow through it may be created which can be measured at its discharge from a hydrant or hydrants at the end of the section under test. If pressures are taken simultaneously during the flow at intermediate hydrants or other connections of known elevation along the main, then, from the data so obtained, the loss of head and the friction coefficients of each section may be computed. Obstructions or closed valves may also be located through the unequal drops in pressure in different sections along the line when such difficulties exist.

Such tests are of value in determining the necessity for or advisability of cleaning a main and likewise, in determining the effectiveness of the cleaning after it has been performed. If they are made periodically after cleaning, valuable data will be obtained as to the speed and degree of the return of roughness in the pipe, thereby indicating the true value of the cleaning and the advisability of recleaning or of cleaning other mains. Also the efficacy of corrosion control procedures will be disclosed and the results of changes evaluated.

In those cases where a company's records are inaccurate, loss of head tests may be quickly made to provide an accurate indication of the size of any main which is in doubt.

When flushing out sediment or other deposits from the pipes of a system it is of great value to make a rough check of the discharge of the hydrants or blow-offs in use in order to be certain that a sufficient velocity has been created in the main or mains supplying that point to properly clean them out. From 4 to 6 feet per second is usually considered the minimum that will effectively flush out a main, so that the material remaining will cause no further difficulty by being stirred up by normal flows.

It is difficult to foresee all of the benefits which may come of making tests such as these on a distribution system. One of the greatest benefits is that, no matter what their nature, they will ordinarily result in an unusually thoughtful and detailed consideration of the system on the part of the men who are operating it. The effort to interpret and account for results, and the resulting further tests, will frequently uncover unsuspected conditions quite different from those which originally suggested the tests.

Acknowledgment—At the request of WATER WORKS AND SEWERAGE, the author has revised and added to an article published by him (Journal of the A. W. W. A. for July, 1930), on the same subject. We believe the practical value of this contribution justifies its re-publication.—*Editor.*

Fire Flows Required for Towns of Various Sizes, by National Board of Underwriters

Population	Required Fire Flow, Gallons per Minute for Average City
1,000	1,000
2,000	1,500
4,000	2,000
6,000	2,500
10,000	3,000
13,000	3,500
17,000	4,000
22,000	4,500
28,000	5,000
40,000	6,000
60,000	7,000
80,000	8,000
100,000	9,000
125,000	10,000
150,000	11,000
200,000	12,000

Over 200,000 population, 12,000 gallons a minute, with 2,000 to 8,000 gallons additional for a second fire.

In residential districts the required fire flow depends upon the character and congestion of the buildings. Sections where buildings are small and of low height and with about one-third the lots in a block built upon, require not less than 500 gallons a minute; with larger or higher buildings up to 1,000 gallons is required, and where the district is closely built, or buildings approach the dimension of hotels or high value residences, 1,500 to 3,000 gallons is required, with up to 6,000 gallons in densely built sections of 3-story buildings.

Commercial Pipe Sizes for Fire Streams*

Number of 1 ½-Inch Hose Nozzles	Ordinary Fire Streams											
	40 Pounds Pressure		50 Pounds Pressure		60 Pounds Pressure		70 Pounds Pressure		80 Pounds Pressure		90 Pounds Pressure	
	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.
1	4	20	6	23	6	25	6	27	6	29	6	30
2	6	40	8	45	8	50	8	53	8	57	8	61
3	8	61	8	68	10	74	10	80	10	86	10	91
4	10	81	10	90	10	99	10	107	12	114	12	121
5	10	101	12	113	12	124	12	134	12	143	12	152
6	12	121	12	135	12	149	14	160	14	172	14	182
7	12	141	14	158	14	174	14	187	14	200	16	212
8	12	162	14	181	14	199	16	214	16	229	16	242
9	14	182	14	203	16	223	16	241	16	257	18	273
10	14	202	16	226	16	248	16	267	18	286	18	303
11	16	222	16	248	18	273	18	294	18	314	18	333
12	16	243	18	271	18	298	18	321	20	343	20	364
13	16	263	18	293	18	323	20	348	20	372	20	394
14	18	283	18	316	20	348	20	374	20	400	20	424
15	18	303	20	339	20	372	20	401	20	429	24	455
	High-Pressure Fire Streams											
	100 Pounds Pressure		110 Pounds Pressure		120 Pounds Pressure		130 Pounds Pressure		140 Pounds Pressure		150 Pounds Pressure	
1	6	32	6	33	6	35	6	36	6	38	6	39
2	8	64	8	67	10	70	10	73	10	75	10	78
3	10	96	10	100	10	105	10	109	12	113	12	117
4	12	128	12	134	12	140	12	145	12	151	14	156
5	14	160	14	167	14	174	14	181	14	188	14	195
6	14	191	14	200	14	209	16	218	16	226	16	234
7	16	223	16	234	16	244	16	254	16	264	18	273
8	16	255	16	267	16	279	18	290	18	301	18	313
9	18	287	18	301	18	314	18	326	18	339	20	352
10	18	319	18	334	20	349	20	363	20	377	20	391
11	20	351	20	367	20	384	20	399	20	414	20	430
12	20	383	20	401	20	419	20	435	24	452	24	469
13	20	415	20	424	24	454	24	472	24	490	24	508
14	24	447	24	467	24	488	24	508	24	528	24	547
15	24	479	24	501	24	523	24	544	24	565	24	586

To convert cubic feet to gallons, multiply by 7.4805.
In calculating above table, the following assumptions were made: Nozzles, 1 ½-inch smooth bore, playing simultaneously, and attached to 200 feet of best quality rubber-lined hose; pressures measured at hose connections; velocity of water in pipe approximately 3 feet per second.

*Reproduced by courtesy of N. S. Hill, Jr.

FLEXIBLE UNDERGROUND PIPE CLEANING CO.

A DIVISION OF FLEXIBLE SEWER-ROD EQUIPMENT CO.
9059 Venice Boulevard, Los Angeles, Calif.
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FASTER PIPE-CLEANING AT LOWER COST

FOR 2, 4 & 6 INCH LINES

By means of the FLEXIBLE Power Drive, illustrated above it, is possible to clean 2", 4" and 6" lines without cutting through traffic intersections, thus eliminating unnecessary traffic congestion.

The use of the Power Drive absolutely does away with the need for disconnecting water meters and facilitates the cleaning of stub ends that cannot be handled by hydraulically driven tools or scrapers.

EXPERIENCED SUPERVISION

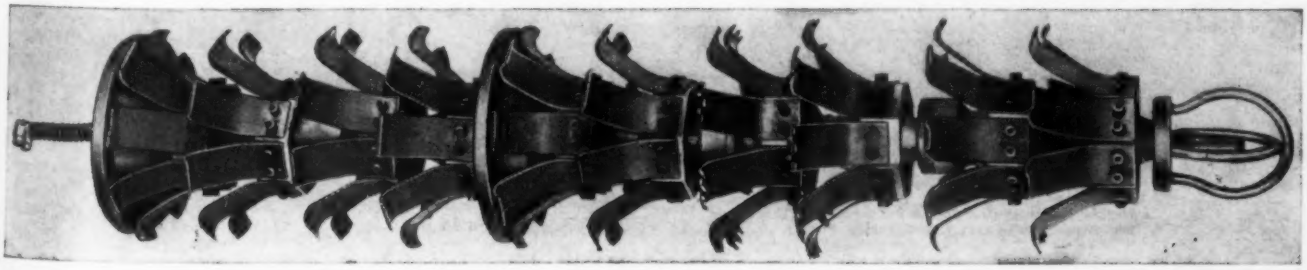
Every FLEXIBLE pipe-cleaning contract is under the direction of an experienced superintendent who has many years of special training and experience with FLEXIBLE'S exclusive tools and methods on all types of pipe-cleaning jobs.

The Flexible Underground Pipe-Cleaning Co. accepts contracts for the cleaning of any type underground line —from 2" to 72". It operates in all sections of the country. Fully equipped service trucks are stationed at strategic locations to speed completion of the work.

JOBS ARE FULLY GUARANTEED

FLEXIBLE workmanship and responsibility are attested by hundreds of customers, whose names will gladly be furnished on request. FLEXIBLE has never failed on a single job and guarantees to clean any job where others fail.

THE PRESSURE LINE SCRAPER



THE NATIONAL WATER MAIN CLEANING COMPANY

Contractors for Cleaning of Water Mains

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910 William-Oliver Bldg., Atlanta, Ga.
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406 Florida Theatre Bldg., Jacksonville, Fla
3812 Castellar St., Omaha, Neb.
205 W. Wacker Dr., Chicago, Ill.
501 Howard St., San Francisco, Calif.
2028 Union Ave., Montreal, Can.

THE NATIONAL METHOD

THE METHOD

The National Method of water main cleaning consists of passing a machine through the main which removes tubercles, incrustations and deposits from the pipe lining. This machine is either water-propelled or cable-drawn through the water main. Thorough cleaning can be accomplished by this method at the rate of approximately 50 to 100 ft. per minute, in sections of from several hundred feet to several miles depending upon conditions.

Briefly, the method involves cutting the pipe in two places, for entry and exit of the cleaning machine, inserting the machine; placing a riser pipe at the exit through which first the muddy water and then the machine emerge; propelling the machine by pressure or by cables through the pipe; finally shutting off the water, removing the riser pipe, and reconnecting the main.

The total time required for shutoff of water in any district is five to seven hours. In an emergency, the pipe can be temporarily made up and service resumed. The work can be done at night if desired.

20" Main in a Midwest City Before Cleaning.

THE RESULTS

The National Method is guaranteed to restore the carrying capacity of pipe to at least 95 per cent of that of new main (The actual result is usually very close to 100 per cent.)

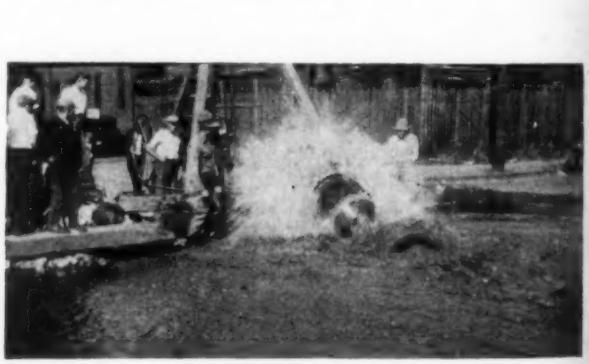
The National Method gives you:

1. **Greater delivery**
2. **Lower pumping costs**
3. **Reduced insurance rates**
4. **Clean water**

LET US CLEAN OUT YOUR CLOGGED MAINS

National experience makes satisfactory cleaning certain. National men know how to meet and overcome unforeseen difficulties that may arise.

When a Pipe Lining Is Tuberculated to This Extent, the Frictional Resistance to Flow Is Considerable.



Machine Arrives at End of Run After Cleaning 30" Main in St. Louis

Information regarding any of the hundreds of successful cleaning projects will be supplied upon request.

WATER MAIN CLEANING

Some Recent Experiences and Results

By WM. S. STAUB, Engineer

West Virginia Water Service Co.
Charleston, West Virginia

WE HAVE just completed main cleaning projects at three of our properties in this state. This, our first adventure in this kind of main restoration, will serve as index of merit of the process. We have definitely raised the flows and pressures in those mains that have been cleaned and, in cases of the transmission mains, the pumping cost per million gallons has been reduced.

"Jacking-In" Operation
About half of a cleaning tool jacked into an 8-in. main. It will travel under its own "steam" by main pressure turned in behind it.

The purpose of this paper is to present our ideas of main cleaning, why we clean mains, what results we have had, the cost per foot to clean; to give a general description of the procedure and to observe what happens in a cleaned main.

In years gone by, when there was no water treatment or when the practice was in its infancy, beyond taste and appearance other characteristics of the water were given little thought. Therefore the distribution system suffered, due to lack of knowledge of corrective treatment. Th edeposition of the solids and the tuberculation reduced the area of the pipe and, therewith, the amount of water that would flow through the pipe under pressure available. Consequently, today, when there are complaints of poor pressure, or when increased fire flow is in demend, we are faced with the problem of main replacements or improvement of existing mains. Although the exterior of the pipe is usually as good, practically, as the day it was installed, the interior may present a scene comparable to the stalagmites and stalactites of the eastern caverns. If such choking deposits can effectively be removed from the pipe and the carrying capacity appreciably restored there will be a great savings over replacements, even though the latter be necessary eventually..

A dirty main is definitely a liability. From the operating standpoint a dirty transmission main consumes many kilowatt hours of power due to the added friction. Kilowatt hours in turn cost money, which in turn increases operating expenses. A dirty main is a great handicap to the fire departments, due to insufficient quantities of water. Poor pressure complaints from consumers are not soothing melodies to a superintendent's ears. Consequently, everyone suffers from the effects of tuberculated pipes.

Locating the Trouble

When a main is suspected of being tuberculated, or when we find that the operating head on a pump is much greater than the static head plus the calculated friction head for new pipe, it is time to find the trouble. The distribution main is isolated in such a manner than all water going to a certain area must pass through the section of pipe to be tested. Then, in the early morning hours, the calibrated pressure gauges are placed along the line and a hydrant is opened at the end of the line. The amount of water is measured with a pitot-tube, the pressure drop is recorded and the loss per 1000' or the value of "C" is determined. (For details of the method see "Hydrant Discharge Measurements," page 183. Reference and Data Number of Water Works and Sewerage, May, 1939.)

We admit this method of determining "C" is not as accurate as secured by Pitometer tests, but we feel that a reasonably accurate value is obtained if precautions are used. In the case of transmission mains, by determining the efficiency of the pumping equipment, static head, operating head, power consumed, water pumped, it is possible to get a very good check over any period. (For "A Simple Method for Checking Pump Efficiencies" see page 445, November, 1939, Water Works and Sewerage.)

Cleaning Procedure

The largest pipe which we cleaned was 10" cast iron. The 10" and 8" pipe was cleaned with the pressure cleaning machine, which uses the water pressure to push the device through the pipe. This machine (see pictures) is about 6' long, composed of five cutting heads and two pistons. The heads are "vertebrae" upon which are attached, around the circumference, the cutting blades. The

The "Carrier"
A rod with leather piston cups is used to thread cable through 4-in. and 6-in. mains.

blades are of spring steel. There are two flexible "pistons" from which the machine gets its drive. There are adjustable ports through the pistons, which we can set to control the volume of water passing the machine for sweeping the debris ahead and, at the same time, to prevent the machine from moving too rapidly. Closing the ports naturally gives added driving power for the tougher jobs. The pistons and cutting heads are on a flexible spring and cable type of shaft. Its flexibility will allow the machine to pass a standard 90° bend. Contrary to the belief of many, the machine does not take on any spiral or whirling motion in its travel.

Cleaning 8 and 10 Inch Mains

The main is isolated and a section of pipe is removed at the point of beginning. This section should be long enough to give ample working room for inserting the machine. The machine is then jacked intothe pipe (see cut) and the pipe permanently jointed either by solid or Dresser sleeves. At that point at which we wish the machine to emerge the pipe is again cut. A short section is removed and bell and spigot fittings are used to rig a riser. Usually this is done with a 45° bend and a short piece of pipe. The joint need only be juted and chained. The purpose of the riser is to discharge the debris on top of the ground, rathre than in the trench. When the riser is rigged the pipe is all ready. The valve on the main is opened slowly to secure the proper amount of water and the machine begins to move. The machine generally moves about 100 feet per minute and it is possible to follow its travel through the line, as the water passing the pistons and the scraping blades is audible at the surface. Generally the water emerging from the riser will only be colored until the machine gets within about 300 feet, then the water is thick and black. The solid material may issue from the pipe like sausage, if the encrustation is marked. In the case of the 3900′ of 10″ line in South Charleston (W. Va.) there was an estimated one and one-half tons of solid material which came from the pipe. The machine will generally lodge in the riser pipe due to so much debris, and has to be helped out. When the machine has reached its destination (after only one trip through in most cases) the riser is dismantled, the main flushed, jointed, and placed in service.

Dollar Losing Debris

Some of the 1½ tons of solid material swept out of 3,976 ft. of 10-in. transmission main, to reduce pumping cost $2.37 per million. (See accompanying tables of data and costs.)

The Safety Winch

Pulling cleaning tool through a 4-in. line. In such operations the debris collects in the ditch, which is dewatered with the small portable pump alongside.

A Small Line "Make-Up"

In which the "carrier" with threading cable attached has been inserted in 4-in. main and is ready to travel.

Cleaning 4 and 6 Inch Mains

In the case of 6″ mains, where they are not so dirty, these may be cleaned by "pressure shots" as described for larger sizes of pipe. In one case where the pressure was low a booster pump was used to supply increased pressure for a 6″ "pressure shot." However, generally 6″ mains must be cleaned the same way as 4″ pipe, which I will now describe.

In cleaning 4″ mains the section to be cleaned is isolated and the main opened at both ends. At the beginning point a small cable is attached to a "carrier" and inserted into the line. The "carrier" is a short rod with leather pistons. The main is then jointed at this point with a portable coupling known as a "make-up." This "makeup" has a gland in the top through which the small cable may be fed. The water is then turned on behind and the water velocity takes the "carrier" and the small cable to the other end of the pipe. This small cable is then used to pull the big cable back to the point of machine insertion. The makeup is removed, the cleaning tool clamped to the large cable (see cut), the main permanently jointed, the water pressure turned on, and the cleaning tool is pulled through the pipe by a gasoline driven winch. This process is much slower than the pressure method and great care must be exercised to prevent breaking the cable and losing the machine. In this case a very slow speed is used. The winch automatically releases the clutch when the tension or pull becomes too great. This generally happens when the cleaning tool caught some joint lead or a bad obstruction. When the cleaning tool emerged the main was flushed and permanently jointed.

Obstacles Encountered

In pressure cleaning the drive of the machine is dependent upon the velocity of the water acting on the pistons, and in the event the machine encounters a cross increasing on the branches it will generally stop. In other words, in cleaning an 8″ pipe, if at an intersection an 8 x 10 inch cross is present the machine will hang. This is due to the pistons expanding and allowing the water to pass it instead of driving the machine.

If the wash water passing the machine is not sufficient to carry the debris ahead the machine will be fouled. We encountered one 8″ main in which the machine would move a short distance, then stop. After the wash water had moved the material ahead the

machine would move again. This happened on a long line where wash water was insufficient and blowoffs were too far apart. The machine had to re-run through this section and I am of the opinion that part of the debris was deposited behind the machine during the first cleaning.

Short radius bends with valves on one side caused several cuts to be made.

Insufficient pressure was a jinx on one job. We were cleaning a 10" main from the reservoir down the hill. The pressure at the point of beginning was only 17 pounds. Thus it was necessary to fill the line with water and bleed it rapidly at the bottom of the hill, thus creating a vacuum. When this was done it was then impossible to keep up with the machine.

Poor joints were responsible for a number of worries—poorly juted joints where the lead had run into the pipe. There were chunks of lead removed weighing 50-75 pounds, old pump gaskets, coil springs, timbers, rocks and, in one case a piece of 1½" pipe about 6 feet long. These had probably entered the system years ago when reservoirs were uncovered or when the pipe was laid.

An Ounce of Obstruction; A Pound of Cure

This section of 8-in. pipe didn't look "too bad," but results after cleaning showed that it was. Proof found in the accompanying tables of data, revealing the "before and after" story, is more convincing than many words about it.

Discoveries and By-Product Values

At Hinton practically the entire system was cleaned. As a result, the method in which tie-ins are made, the fittings, and location of mains were definitely established. I know that our superintendent there can now point out on the ground just what is at every intersection, because he made intersection cards accurately during the cleaning.

There were cases when a pipe which was supposed to be was not and vice versa. Old valves were found, some with box and all gone, some with stem broken and some found partly closed.

If anyone operating a water system, which has been in service for a number of years, attempts a job of main cleaning, he will probably be surprised at a great many things found. And, from the operating standpoint, the knowledge gained during cleaning of mains may well save a few nights sleep to the superintendent.

Conclusions

We feel that our main cleaning jobs have done a lot of good. Those who have seen the mains before and after know that flows have definitely been improved. Just how long this pipe will remain clean is another question, but we expect to keep a close check on the cleaned mains. In fact, we are taking daily samples at all points where we cleaned and are recording the pH, alkalinity and CO_2. Periodic flow tests will also be made to ascertain to what degree the main is tuberculating. We are trying to control our corrective-water treatments accordingly.

We do know that the fire flows have been greatly increased and that once weak hydrants are again gushing brisky. On transmission mains there have been definite and pleasing reductions in power consumed.

Costs and Cleaning Data

In the accompanying tables something of the data pertaining to cleaning operations and costs are presented for the benefit of those interested.

TABLE 1—Charleston Main Cleaning

Item	Pipe 6" Kanawha St.	Pipe 8" Va. St.	Pipe 10"** So. Chas.	Pipe 10"-8"** Nitro Line
Contract of Cleaning	$134.80	$271.70	$397.60	$1,488.95
Material Cost	6.19	48.86	138.29	250.40
Labor Cost	65.86	186.80	188.14	888.09
Total Cost	206.85	507.36	724.03	2,627.44
Number of Feet Cleaned	1348	2717	3976	29779
Cost per Foot	$ 0.1535	$ 0.187	$ 0.1823	$ 0.0834

* This cost does not include 8" temporary steel line which was laid. The rental of pipe, placing and removing cost $1,757.75 for 4200'. If this were added to the above the cost per foot for cleaning the 10" main would be $0.625.

** The 10" and 8" main is a transmission main and was cleaned as one unit. Therefore there was no breakdown in cost.

TABLE 2—Charleston Main Cleaning (Transmission Main)

Location	Size	Feet of Pipe Cleaned	"C" Before Cleaning	"C" After Cleaning
South Charleston	10"	3,976	66	130*
Nitro-Dunbar	10"	10,679	49	130
Nitro-Dunbar	8"	19,100	49	126
Charleston-Virginia St.	8"	2,717	—	138
Charleston-Kanawha St.	6"	1,348	—	115

* Yielding an estimated savings in pumping cost (power) of $2.37 per M.G. for the South Charleston main.

TABLE 3—Hinton Main Cleaning (Total Cleaning Costs)

Item	10" C.I.	8" C.I.	6" C.I.	4" C.I.
Contract of Cleaning	$177.40	$ 546.90	$255.60	$ 675.80
Labor Costs	42.92	238.33	185.60	376.86
Material Costs	44.25	245.54	189.30	301.96
Total Cleaning Cost	264.57	1,030.77	630.50	1,354.62
Cost per Foot	0.15	0.189	0.246	0.20

TABLE 4—Hinton Main Cleaning

Pipe Size	Ft. of Pipe Cleaned	No. of "Shots"	Max. Length "Shot"	Min. Length "Shot"	Ave. Length "Shot"	"C" Before Cleaning	"C" After Cleaning
10"	1,774	1	1,774'	1,774'	1,774'	—	128
8"	5,468	9	1,072'	215'	608'	48	126
6"	2,556	7	675'	189'	365'	80	117
4"	6,758	14	965'	36'	482'	44	122

TABLE 5—Sutton Main Cleaning

Item	Pipe 6" Main St.	Pipe 4" Town Hill	Pipe 4" South Side
Contract of Cleaning	$177.00	$325.40	$487.50
Material Cost	18.55	72.60	105.60
Labor Cost	90.50	166.40	249.20
Total Cost	285.85	564.40	842.30
Number of Feet Cleaned	1770	3254	4875
Cost per Foot	$ 0.161	$ 0.173	$ 0.172

TABLE 6—Sutton Main Cleaning

Location	Size	Ft. Pipe Cleaned	"C" Before Cleaning	"C" After Cleaning
Main Street	6"	1,770	42	136
Town Hill	4"	3,254	68	118
South Side	4"	4,875	71	117

DRILLING AND DEVELOPING DEEP WELLS

By J. ARTHUR CARR

Superintendent of Water, Ridgewood, N. J.

The author of this article has for several years served as co-chairman with Jas. A. Harding of the A. W. W. A. Committee on Deep Wells and Deep Well Pumping.

WHILE some of the ideas expressed in this article are applicable to wells of all types, they are offered chiefly from experiences in the construction of wells in the red sandstone formation, such as is encountered in Northern New Jersey.

In the writer's opinion, the most important points in the construction of a new well are:

1. Full and complete specifications and a bid sheet permitting a fair comparison of prices.
2. The selection of a qualified contractor.
3. A full-size hole that is plumb.
4. Proper sealing.
5. Proper and complete testing.

(1) Specifications and Bid Sheet

The preparation of specifications is not as simple a matter as it may appear if the interests of both the purchaser and contractor are to be safeguarded. There are several points both in the specifications and bid sheet which, unless they are carefully covered, may cause difficulty in deciding the low bidder and create misunderstanding in making payments.

Usually the most expensive portion of the well is the portion which is cased down from the surface and into rock. Frequently the depth into rock to which the casing will be carried cannot be determined in advance. In order that all bids may be considered on a comparable basis, it is recommended that a statement be made in the specifications similar to the following: "For the purpose of comparing bids, the distance from ground surface to rock will be considered to be .. feet," the distance mentioned being the approximate depth the rock is believed to be.

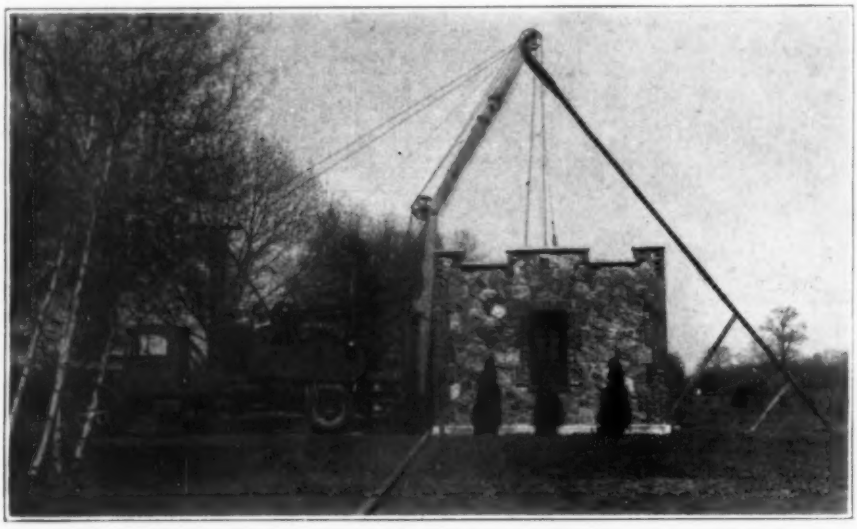
The depth to which a well is to be drilled is also frequently difficult to state beforehand. So that bids may be comparable, a statement such as follows is advisable: "While the contractor's bid is based upon a maximum depth of .. feet, it is understood that drilling may be stopped at any depth by the engineer; however, it is guaranteed that the contractor shall be paid for at least .. feet of drilled well."

The cost of at least one test should be included in the bid price. In addition, the specifications should stipulate the amount to be paid for any additional testing which may be required. This amount is usually set up on an hourly basis.

(2) Selection of Drilling Contractor

Next in importance, after bids are properly filed and evaluated, is the selection of a skilled and experienced contractor. The contractor selected should be one who is not only financially responsible, but more important, one who knows how and has the equipment to do a first class job and also the desire to do it. In this connection, a method which embraces the requalification of bidders is desirable.

Full and accurate records are most essential for the proper future operations of a well. There should be absolute insistence that the contractor keep and turn over to the owner detailed information as to what is being done and what is happening as the work progresses. Samples of drillings at various depths should be preserved and the location of any change in formation noted.



Deep Rock Well Development, May, 1942, Ridgewood, N. J.

Here is seen the machine developed to work over the tops of existing well houses. This development work on these rock wells improved yields from 50 to 200 per cent—something heretofore not considered possible.

(3) A Plumb and Full Sized Hole

It is poor economy to drill holes that are likely to later prove too small. The hole should be started of sufficient size to permit as many reductions in diameter as may be necessary and still have ample diameter for the installation of a pump of high efficiency.

During construction, a well should be plumbed and gauged at frequent intervals in order that the purchaser may be assured a straight and plumb hole of full required diameter. Watching the cable to see that it hangs in the center of the hole is a rough check for plumbness. Bit diameters should also be frequently checked.

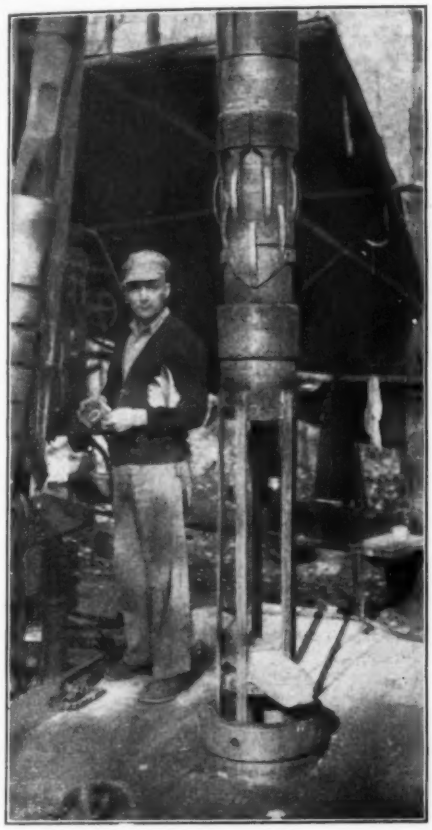
While a hole that is straight, although slightly out of plumb, does not interfere to any great extent with a pump setting, a

zigzag or corkscrew hole, or one with flat spots or constrictions in diameter, may cause much trouble and expense.

(4) Proper Well Sealing

In the writer's opinion, there is only one sure and permanent method of sealing a rock well to shut off surface or top ground water, and that is by double-casing and cement filling the annular space between the two casings. The inner casing may be installed either before or after completion of drilling and should extend well past all soft or broken formation near the surface of the rock. If the inner casing is placed before the completion of drilling, care should be taken to avoid jarring and cracking the cement during subsequent drilling operations.

Considerable care should also be exercised in placing the cement to avoid bridging and to entirely fill the space between



View of the Top of the Double Packer Used in the Surge Treatment.

casings. In placing the cement, the method most frequently used is to pipe the cement slurry all the way to the bottom of the space to be grouted. Grout should always be applied as one continuous operation.

(5) Testing

Tests should be made with a pump of sufficient capacity to handle more water than it is expected the well will produce and with the pump set at a lower level than the maximum anticipated draw down. This should be done so that the maximum yield and the yield at different draw down levels may be determined.

Opinions as to the duration of tests vary. The writer favors 72 hour tests of continuous pumping, especially in new well fields or where there is a possibility of interference with other wells. For 60 hours the well is pumped at maximum capacity and draw down. Usually after the first 24 hours a point is found where the well stabilizes and the level does not change. The well is then pumped at that level until the 60th hour. The pumping rate is then gradually reduced at intervals of about 1 hour and the draw down at different capacities noted. By this method a good record of the capacity of the well at different drawn down levels is obtained. From this data the most economical pumping level may be selected—a matter of considerable importance when considering the day-after-day costs of operation.

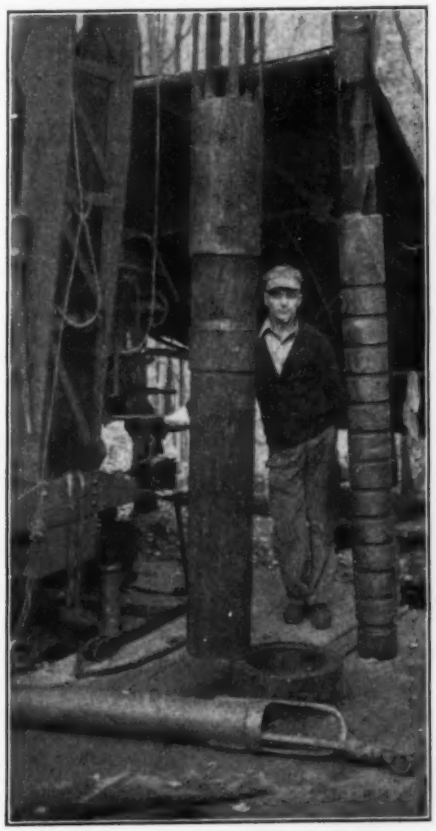
Some Notes on Developments

In the paragraph relative to plumbness and size, mention was made of development. In the past it has generally been accepted that when the drilling of a rock hole is completed, nothing further can be done to increase the yield. From his experiences in Ridgewood during the past two years, the writer is convinced that the odds in favor of increasing the yield in rock wells can be bettered by application of some of the methods of development heretofore used only in the development of sand and gravel wells.

During 1940 two Ridgewood wells were developed, using the conventional valve type surge plunger such as is used in sand wells. The capacity of one well was increased 30 per cent and that of the other well 200 per cent.

In the course of agitation of those wells, many cubic feet of sand, clay and pieces of rock were brought into the well. Along with the other material were many small pieces of cement which seemed to indicate that practically all of the action due to agitation was taking place immediately below the casing. This seemed to indicate that better results would be obtained if the effects of agitation could be spread over the entire well wall.

With that thought in mind, a steel cage-like structure 30 feet long with a temporary seal at top and bottom was constructed. This device was then suspended on a string of pipe and lowered to the bottom of the next well constructed. The well was then developed for several days, using a long, heavy, steel plunger



Lower Section of the Double Packer and the Agitator Used.

in place of the conventional one. The packers were raised at varying intervals of time until the well wall had been exposed to agitation for its full depth. This method of development was used on four wells during 1941 and the capacity of all was increased, the amount of increase ranging from 50 to 200 per cent.

Early in 1942 development was applied to a well built in 1932. This well was producing 80 GPM at a pumping level of 120 feet. After development the well is producing 170 GPM at the same level.

TREATING INCRUSTED WELLS

Effective Means of Increasing Production at Critical Periods

By JOHN R. GOETZ and F. L. COVENTRY

Superintendent *Chemist*

Water Department, Mattoon, Illinois

SOMEONE has very aptly explained corrosion as the process of the return of a metal to the composition in which it is found in nature—in other words, a return to nature through natural processes. For example iron ore and rust are one and the same chemically.

Incrustation is, on the other hand, a deposition of material. Incrustation with which this paper deals results in the clogging or stoppage of well screens and/or water bearing formations. It is the result of deposition or collection of material in and about the openings of the well screen and the voids of the water bearing sands or gravel. It is usually hard and cement like; but it may be soft and gummy. Where the water is of an depositing nature, incrustation will appear sooner or later, and it is of importance to give careful consideration to all methods for the prevention or retarding of incrustation.

Naturally such choking deposits cause a marked decrease in well yields and something must be done about it.

Well Treatments to Boost Yield

In general, there are two successful methods for treating incrusted wells, namely, (1) pulling the incrusted screens, treating them for the removal of the incrusting material and resetting them; (2) treating the screens in place without pulling them.

It is obvious that the first method is effective but it involves considerable risk and labor. If the incrustation is very hard it sometimes requires immense power to withdraw the screen, occasionally resulting in breaking the pulling pipe, or damaging the screen. There is also some risk involved in replacing the screen after treatment. Treating the screens without pulling them with acid is not a new discovery so far as the use of the acid is concerned, yet we found very little information and less experience by water works operators in the use of the method.

Our treatment of a well involves the use of muriatic acid (hydrochloric acid of commerce) which can be purchcased in convenient containers or carboys, usually of 12 gallons capacity. Full strength acid should be used and at least enough to fill the screen. As shown in the illustrations a length of garden hose about ¾ or 1 inch in diameter, and of sufficient length to extend to the *bottom* of the well, should be obtained. Provision should be made for wiring the hose in place as to depth in the well. The hose is lowered until it is within a foot or so of the bottom of the screen. If the screen is more than three or four feet long it is well to add enough acid to fill one foot of screen, then lift the hose one foot and add more acid. (Note—in the picture, you may see the rule and the wire which is fastened to the hose down in the well.) Into the upper end of the garden hose is taped (tire or friction tape) a length of small rubber tubing. The other end is connected to the carboy by means of a glass tee. A rubber syringe bulb is also attached to the tee to enable the operator to prime the acid "syphon." The amount of acid for each foot of screen is calculated ahead of time, and can be checked by the rule as the level drops in the carboy. Example: A 10-inch screen will require about four gallons per foot, or one-third of the height of a 12-gal. carboy.

The hose end is lowered to the *bottom* and worked upwards in order to produce as little dilution of the acid as possible. The acid being heavier than the water, will displace the latter, but it mixes with water so readily that it is easily diluted.

The acid charge is permitted to stay in contact with the screen for twelve hours, during which time the drop pipe and pump may again be installed ready for operation. Since we have a lime-soda softening plant we merely start the well pump and allow the operation of the plant to compensate for any excessive acidity in the first water coming from the well.

Our experience has shown that as much as a 40% increase in well production followed the acid treatment ot the well.

A Few Precautions

Necessary conditions for acid treatment of wells are:

1. The well screen must be constructed of metal which will not be damaged by acid. Brass or bronze screens require muriatic acid, while iron requires nitric acid.

2. The screen must be constructed of one metal to avoid establishing rapid galvanic corrosion which would greatly damage the screen.

3. There should be some definite knowledge of the kind of incrusting material so as to determine the proper acid. Samples of incrustation taken from other wells in the locality are usually available. In the absence of such samples an analysis of the water will usually indicate the proper procedure.

Well Treatment Set Up

The drop pipe is up and swung to one side out of the way. The rubber hose is down in the well, the lower end resting on the bottom, and the first charge of acid is applied. The hose is hung from the wire seen by the rule, and is drawn up a foot at a time during the emptying of the carboy sufficiently to completely fill the screen. The drop pipe is returned to the well and twelve hours or so later the well is pumped free of residual acid and returned to service. Note the carboy tubing arrangement, and the bulb for starting the acid syphoning itno the dosing drop hose.

EMERGENCY REPAIR OF DISTRIBUTION SYSTEMS*

By W. VICTOR WEIR
Superintendent
St. Louis County Water Co.
University City, Mo.

IF EMERGENCY distribution system repairs are to be handled in the least possible length of time, there must be careful preliminary planning. Everyone involved must be instructed and trained, and proper equipment must be provided. In spite of the fact that distribution system repairs are in most instances handled with dispatch, there is probably room for some improvement in every organization. The wartime requirements that water supply be uninterrupted to war production plants, and the wartime hazard that emergency repairs in amounts heretofore unthinkable may be required, indicate the need for a review of past and current practices. Thought must be directed not only along the lines of what has happened in the past and what has been done as a result, but what may happen and what new methods and equipment are available for use in such emergencies.

This paper may well be divided into the same steps as are followed when emergency repairs of a water works distribution system are required. First, someone is notified that repairs are needed. Second, men are dispatched to the scene. Third, they determine what needs to be done. Fourth, they do it.

The First and Second Phases

The first phase is the notification that an emergency exists. A message must be transmitted to a proper party in the water department. Where night telephone service is maintained, the problem of notifying the proper party, by relaying the message, is readily handled. This night service may be obtained by having a watchman answer phone calls. It may be handled by routing all calls to some station where men are on 24-hour duty. Again, it may be foud advantageous to have certain jobs performed at night, such as auto maintenance work, so that one or more men will be available to the telephone at all hours.

The second phase requires the dispatching of men to the scene of the incident. When the description of the damage suffered is full and lucid, a proper-sized crew can be dispatched. If, however, the description is meager, or is simply that "our water is off," it may be necessary to send one or more men to reconnoiter the situation.

When an intelligent report comes in, a proper crew and equipment can be dispatched. In several actual instances, where considerable areas were out of service, the intelligent report has come through after long delay, simply because the telephone lines were overloaded with futile but well-meaning messages that there was no water service. To prevent such a breakdown of telephone communications, many utilities have installed unlisted telephones in their service departments, the numbers being known only to foremen and other key men. These men are thus able to obtain telephone communication when the regular lines are swamped with calls which make them practically useless.

In the larger cities, regular night crews are often available on duty to handle off-hours' emergency work. These men may play pinochle four nights out of five, or they may perform some duties, such as repair work, which can be dropped immediately upon receipt of an emergency call. One large city water department uses its night crew to perform construction work, to be dropped in the event of an emergency. This crew is contacted by police radio when it is needed.

For most cities, the employment of a night crew is out of the question. The off-hours' emergency work must be performed by men called away from their homes. In these cases, men must have telephones and night gangs should be staffed with men living near each other, so they can quickly be picked up.

In the event of occurrence of multiple emergencies, it may be necessary to call out several crews at once. The calling of many men can best be done by the "chain" method. Only one man from a crew is called, and he, in turn, calls the rest of his crew; or two key men are called, and they each call two or three other men. Preparation for multiple emergencies require the designation of crew personnel ahead of time. Each man must know with whom he is to work and where he is to report. These schedules must be worked out in advance and each man should carry written instructions regarding his individual duty. Properly organized, a few telephone calls should set into motion a whole train of scheduled activity, enabling manpower mobilization in the shortest possible time.

*This paper, presented at the A.W.W.A. Conference on Wartime Water Works Problems, is reproduced by permission of the Association.

The All-Important Third Phase

After men have been dispatched to the scene, we enter the third phase—what is to be done? Great volumes of water may be gushing up through the pavement. Valves must be closed. Which valves? And where are they? In these times, it is no longer excusable to have the valve locations in the photographic mind of a man who is sick at home. Neither is it excusable to have a good set of records at the office or on the single emergency truck now required to be several places at one time. The ideal situation provides each key man and each foreman with a distribution system layout and a complete set of valve records.

These records for use in the field must be complete, simple, not bulky, and easily provided, in as many copies as may be necessary. For small systems, several methods of preparing distribution system records are acceptable. For large systems, the plat and list method as outlined in the A.W.W.A. Recommended practice for Distribution System Records (Jour. A.W.-W.A., 32: 181 (1940) is extremely satisfactory and flexible. Too much stress can not be laid upon the necessity for adequate field records. The time available for their preparation is all too short, but their importance requires adequate preparation of this vital assistance during emergencies.

The fourth phase of the problem of emergency repair is simple—the men do it. The proper valves are closed. The excavation is made and de-watered. The pipe is repaired. Service is resumed. All this takes time, and the time involved depends upon the ability of the crew members, their training, their tools and the repair materials used. The job may take as many hours as the inch-diameter of the main if the piece to be replaced is a fitting. Half that time may be average if it is a broken pipe and a permanent repair with a solid sleeve is made. The time may again be cut in half if the repair is made with mechanical joint repair materials.

Speedy repair is important. No water is available in the affected area for industrial, sanitary or fire fighting purposes. Proper organization and proper equipmeent are required if the water works man is not to do "too little, too late."

Equipment

All too often the record shows that it took some other water department from four to six hours to close off a ruptured main. The right valves were not closed at first; or an unknown pipe line had been tied into the closure section. The time involved in closing two or three large valvees and a few small ones, if the affected main is large, is not inconsiderable. Even three hours might be excellent time if several large valves must be closed manually. The need for power operated valve operating equipment becomes obvious where many large valves are in use. This equipment may be truck mounted, driven from a power take-off, or it may be motor-driven from an air compressor or portable electric generator.

If the repair must be made at night, artificial light in generous quantity should be provided. Acetylene generators or portable electric generators should be available on trucks answering night calls. The electric generators are probably the most satisfactory, since the entire site can be flooded with light from a very small amount of easily portable equipment.

If the excavation must be made through concrete, either a compressor with suitable tools or a gasoline-powered paving breaker should be available.

Where the pipe to be repaired is 20 in. or larger in diameter, the use of a truck-mounted crane, a common piece of contractor's equipment in a large city, will speed up both excavation and repair. A clam-shell bucket will make quick work of the wet excavation and the heavy pipe can be handled with ease. Tripod derricks made with 2-in. pipe legs will be strong enough for 20-in. pipe fittings, if handled properly.

Self-priming gasoline engine centrifugal pumps are "musts" on speedy repair work. Rather than purchasing trailer-mounted pumps, it will be advisable to put the same amount of money into smaller, more readily portable units, using two or more on a large repair job. If one small pump fails, the job still goes on. If a large pump fails, the repair job stops until the pump can be made operative.

When the pipe to be repaired must be cut, the use of a pipe

cutting machine may be advantageous. The cutting time can be shortened by using an air motor for power. A heavy duty electric drill or flue roller can also be used for power, being driven by a portable electric generator of 1½ kw. or larger capacity.

Mechanical Jointing

With the pipe excavated and de-watered, the remaining work may take considerable time if lead joints and solid sleeves are used in making the repair. The use of mechanical joint solid and spit sleeves, or a combination of them, will speed the job a great deal more.

With the use of mechanical joint repair fittings, the valve closures do not have to be as good as when poured joints are used. Neither does the excavation have to be as completely de-watered, since the bolt-fastened joints can be made under water, if necessary. Also, pipe ends do not have to be carefully cut off. Fittings are available which will cover jagged pipe ends with ease.

While cast-iron pipe as a rule still uses the bell and spigot method, the use of mechanical joint fittings for making repairs is becoming comparatively common. The higher cost of these fittings as compared with poured joint fittings is largely offset by the saving in labor cost due to shortening up the time of repair. One man less is generally required on the repair crew since there is no need for a lead man. The use of mechanical joint fittings will receive a boom during this war emergency, but the increased use of these fittings is here to stay.

With the possibility that numerous repair crews may have to be put in the field at one time, if multiple incidents occur, these crews will necessarily be smaller than usual or the men will be inexperienced. The use of mechanical joint fittings will allow inexperienced men to make good repairs after very little training, while it would take a great deal more time to develop lead melters and calkers.

Wooden Plugs

Wood is often an excellent material to use in making temporary repairs. Small holes can be stopped with wood plugs. These plugs can be sawed off flush, drilled out with a tapping machine and the permanent repair made with a brass plug.

In some cities, properly tapered wood plugs are used to plug the ends of 4-, 6-, and 8-in. mains. The plugs, of course, must be blocked or otherwise secured to keep them in position when pressure is built up in the main. The use of wood plugs offers a very quick way to stop water wastage where a number of small mains, 4 to 8 in. in size, are broken. If found desirable, these plugs could be bored and smaller steel pipes driven into the plugs so that connections between ends of severed mains could be made temporarily with hose.

One way to minimize the time required to make water main repairs is to have the necessary materials stored as near the repair job as possible. Since it is impossible to know where the emergency will occur, the best procedure is to have small but adequate stocks of pipe and fittings stored at various points on the distribution system. It will then be unnecessary for the repair truck to go to a central storeyard, often several miles from the broken main, to get the necessary materials. Whenever anything is removed from one of these material caches, it should be reported and immediately replaced. All crews should carry lists showing the amounts of material available at each place.

Sterilization

Sterilization is essential after distribution system repairs are made. The valves which are closed to segregate the affected portion of the distribution mains should not be opened as soon as the repair is made. The crew foreman or other responsible man will have to study the piping layout to determine how the probably contaminated section can be properly flushed and then sterilized. After flushing, hydrochlorite or other chlorine solution should be fed into one end of the affected piping and allowed to disperse through the section by drawing water from the other end. After an adequate contact period, while the water in the main contains from 50 to 100 ppm. of chlorine, the main should again be flushed before being placed in service. In sterilizing and flushing, it may be necessary to close down one or more additional valves to get fire hydrants into the affected portion of the pipe system so that proper flushing and sterilizing can be done.

Foremen's schools may be necessary to teach the proper procedures in flushing and sterilizing mains. A number of problems involving repairs at selected spots in the distribution system will convey to the foremen the procedures to be followed. It is difficult to state categorically just how sterilization should be done. A dozen different procedures might have to be followed in a single distribution system, depending upon the spacing of hydrants and valves.

Equipment for sterilizing must be provided. Small iron force pumps with rubber check valves are fine for sterilizing small mains with hypochlorite solution. Larger mains will require power pumps with large solution crocks or gas-feeding equipment. Since similar equipment is necessary in sterilizing newly laid mains, the purchase or construction of these items can not be considered to be an extravagance.

Radio communication should be utilized wherever possible. Due to the present impossibility of constructing new short wave stations, the best chance is the use of police radio assistance where it can be obtained. While two-way communication will not be possible under most circumstances, receivers can be had or converted to use so that medium high frequency police stations can be received. It should be borne in mind that radio may not be worth a great deal if telephone service is gone, since it may be very difficult to get a message from the water department to the police department broadcasting station. Messenger service may have to be planned.

TO STOP PIPE SWEATING*

The following formula, directions for application, and specifications for materials required in the application of an insulating protective coating for stopping troublesome sweat formation on pipes, pumps, small tanks, etc., has proved highly satisfactory according to Chas. P. Hoover, Consulting Chemical Engineer and 1st Ass't. Superintendent of Water Works at Columbus, Ohio.

Application Procedure

All surfaces must be absolutely clean and dry before any applications are made. The outside surface is first painted with a thick coat of adhesive (specified herein), after which a thick coat of ground cork is either blown or pressed on by hand. This ground cork must be built up to a uniform thickness on all exposed surfaces. After this application is thoroughly dry, a second thick coat of adhesive is applied, after which the second thick layer of ground cork is either blown or pressed on by hand. The second layer of ground cork must also be built up to a uniform thickness. After the second application is thoroughly dry, it is covered with two coats of an approved paint.

The Adhesive

The adhesive is made up of the following materials:

Ingredients	*Proportions*
Whiting, dry	7¾ lbs.
Interior Varnish	4¼ lbs.
Raw Linseed Oil	¼ lb.
Paint Dryer	¼ lb.

Cork Specifications

In purchasing the cork to be used the following specifications will be found helpful:

The cork shall be equal in quality to 8/14 granulated cork as manufactured by the Armstrong Cork Co., Lancaster, Pa. It shall be ground so that not less than 95% by weight of the particles will pass through a No. 8 U. S. standard sieve and not more than 5% by weight will pass through a No. 14 U. S. standard sieve. The cork shall not weigh more than 8 lbs. per cubic foot. The cork shall contain not more than 1.5% of dirt, dust, or other foreign matter.

It is to be noted that all of the above, with slight changes in a word here and there, will produce a complete specification for materials as well as the method of application should the insulating job be let to contract.

*By Chas. P. Hoover, Principal Ass't Superintendent, Division of Water, Columbus, Ohio.

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For BELL *and* SPIGOT PIPE

Tegul-MINERALEAD is a radically different jointing compound with advantages not matched in total in any other product for its purpose. Its sulphur base includes, as a plasticising agent, a special olefine polysulphide which contributes these advantageous properties:

GREATER ADHESION TO METALLIC AND CERAMIC SURFACES • HIGHER RESISTANCE TO VIBRATION and to MECHANICAL SHOCK and TEMPERATURE CHANGES • GREATER PLASTICITY and LOWER COEFFICIENT OF EXPANSION. Using *Tegul*-MINERALEAD you may expect:

SPEED — Initial leakage will be much less than usual and what there is will be taken up in much less than the time usually required. This permits immediate back-filling and prompt clearing up of traffic hazards arising from open trenches.

CONVENIENCE — Molded in 10 lb. ingots, *Tegul*-MINERALEAD is easier to handle, ship and store. The ingot is impervious to moisture, so may be stored outdoors in any weather. Since there can be no change of composition in an ingot, *Tegul*-MINERALEAD reaches you as correctly mixed as when it left our factory.

ECONOMY — *Tegul*-MINERALEAD weighs only 1/5th as much as lead (and goes 3 times as far) saving in shipping costs. 5 ingots to carton makes a handy package. It melts, pours and sets quickly, needs no caulking or deep bell holes and requires no skilled labor. The sum of *Tegul*-MINERALEAD'S advantages makes it a money-saver too.

RESISTANCE TO SHOCK — Higher resistance to mechanical and thermal shock promises permanently tight joints. Lines laid with *Tegul*-MINERALEAD in every kind of terrain and meeting every kind of punishment, have served for years without need of attention.

AVAILABILITY — *Tegul*-MINERALEAD is stocked at conveniently located points and is usually available on short notice. Using *Tegul*-MINERALEAD helps conserve lead, a strategic war metal.

HOW *Tegul*-MINERALEAD IS USED

MELTING — *Tegul*-MINERALEAD melts at 248°F., requiring only a slow fire. Care should be taken to avoid direct contact with flame and overheating, which tends to cause the compound to thicken. Best results are had by using furnace designed by the manufacturers of *Tegul*-MINERALEAD.

YARNING—The pipe at Bell and Spigot must be clean and free from accumulations of oil, tar and grease. If jute is employed, it should be the dry, braided type.

POURING — See that joints are clean. Use mud on asbestos runner to prevent adhesion to the *Tegul*-MINERALEAD and to seal any leaks. Pour the melted compound slowly through a high pouring gate, using ladles or pouring pot of sufficient capacity to fill the joint at one operation. Add whole or half ingots to replace *Tegul*-MINERALEAD used. It is not necessary to wait for complete melting before pouring more joints. Cut off pouring gate when compound has solidified. Remove runner and joint is complete.

POURING WET JOINTS—Follow same general procedure as above except that runner must be held away from bell at bottom of joint to provide outlet through which the *Tegul*-MINERALEAD can drive out the water. When the compound flows freely through this opening, close with clay and continue pouring until gate is full. Better results are obtained when *Tegul*-MINERALEAD is heated to just below the thickening point.

This table shows relative amounts of *Tegul*-MINERALEAD, as against lead, and amounts of braided jute required to make approved joint in A.W.W.A. Standard Pipe.

Nominal Inside Diameter of Pipe In Inches	Pounds of *Tegul*-MINERALEAD per Joint Using 1 Ring Braided Jute	Pounds of *Tegul*-MINERALEAD per Joint Using 2 Rings Braided Jute	Pounds of Lead per Joint	Pounds of Braided Jute Using 1 Ring	Pounds of Braided Jute Using 2 Rings
4"	1.9	1.6	7.5	.10*	.20*
6"	3.0	2.4	10.25	.13*	.25*
8"	4.6	3.9	13.25	.17*	.34*
10"	5.5	4.7	16.	.20*	.40*
12"	6.5	5.6	19.	.24*	.48*
14"	7.5	6.4	22.	.27*	.54*
16"	10.1	8.7	30.	.45†	.90†
18"	11.7	9.7	33.	.51†	1.02†
20"	12.6	10.8	37.	.57†	1.13†
24"	14.9	12.8	44.	.66†	1.32†
30"	18.4	15.8	54.	.83†	1.65†
36"	22.2	19.	65.	.92†	1.83†
42"	29.5	26.5	75.	1.13†	2.25†
48"	33.3	30.3	85.	1.28†	2.55†

* Use ½" jute on this size
† Use ⅜" jute on this size

Add 15% to above *Tegul*-MINERALEAD amounts, if pipe to be used has no bead on the spigot end.

We also manufacture
G—K SEWER JOINT COMPOUND

the Original Bituminous Jointing Compound
for Vitrified Tile and Concrete Sewer Pipe

Amounts of G—K Compound required per joint, based on A. S. T. M. Terra Cotta Pipe dimensions.

Size of Pipe	Depth of Joint	Cubic Inches of Compound	Pounds of Jute	Pounds* G—K
4"	1¼"	8.2	.03	.52
6"	1¾"	19.2	.04	1.22
8"	1¾"	31.2	.15	1.98
10"	1¾"	38.1	.26	2.42
12"	1¾"	48.2	.31	3.07
15"	1¾"	55.	.40	3.5
18"	2¼"	83.7	.47	5.31
21"	2¼"	120.1	.65	7.59
24"	2¼"	136.5	.74	8.58
27"	2½"	202.2	1.29	12.87
30"	2½"	250	1.65	15.9
33"	3"	328	1.76	19.5
36"	3"	450	2.44	28.8

* This calculation is based on 10% excess for possible waste

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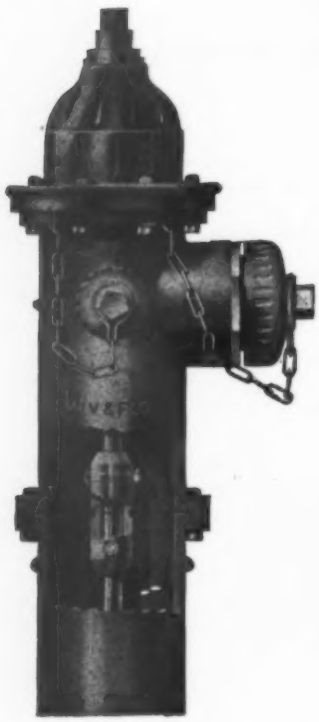
ANNISTON, ALABAMA

VALVES, HYDRANTS AND WATER WORKS ACCESSORIES

Protection of public water systems and fire protection for municipalities under war conditions involves a greatly increased number of control valves and hydrants on the water mains. M & H products with their record of high quality, rugged strength and dependability can safely be recommended.



M & H FIRE HYDRANTS

Conform to latest A.W.W.A. specifications. Simple, rugged design minimizes maintenance costs. Features are:

1. Dry Top—Operating threads protected from action of water. No rust, corrosion or freezing.
2. Easy Lubrication of operating nut, threads and packing through lubricating screw in top of operating nut.
3. Revolving Head, outlets faced in any direction.
4. Addition of Steamer Nozzle, without digging up hydrant or requiring complete new barrel.
5. Lengthening of Hydrant without digging up or requiring complete new barrel.
6. Double Lead Gaskets on Bronze valve seat.
7. Removal of Bronze Seat, or any working part, without digging up Hydrant.
8. Double Drain Valves, absolutely positive, insuring quick and complete draining of Hydrant.
9. Lugs on Bell of Hydrant Shoe for strapping to the water main, if desired.
10. Compression Type. Water pressure keeps valve tight.

SPECIAL TRAFFIC MODEL FIRE HYDRANT

Equipped with cast iron bolts and breakable coupling on the stem. Breakage due to traffic collision is limited to these cast iron parts which are easily and quickly replaced without shutting off the pressure.

M & H A.W.W.A. GATE VALVES

Iron body, bronze mounted gate valves are furnished in the double disc parallel seat or solid wedge types with non-rising stem, outside screw and yoke, or with sliding stem and lever. Supplied to fit any standardized pipe connections. By-pass valves can be furnished, unless otherwise specified, in sizes according to A.W.W.A. specifications.

SPECIAL TYPES

Hydraulically Operated: for remote control of operation and for quicker, easier opening or closing. Can be supplied in any of the standard sizes of M & H A.W.W.A. gate valves, either high or low pressure.

M & H Square Bottom Gate Valves: specially designed for operation in any position. Patricularly recommended for use in intake towers or at the foot of dams; for pressure regulation by throttling the flow of water in centrifugal pump discharge lines; for regulation of flow in feed line to a filter bed; and for flow regulation from a reservoir where there is unbalanced pressure against the gates.

PRESSURE CLASSIFICATION—2″ TO 30″ SIZES

Class	Working Pressure	Hydrostatic Test
AA	0 - 25 lb.	50 lb.
A	26 - 50 lb.	100 lb.
B	51 - 100 lb.	200 lb.
C	101 - 200 lb.	350 lb.

CHECK VALVES

For intsallation in horizontal or vertical position. Can be supplied with by-passes. May be furnished with outside lever and weight. Sizes from 2″ to 12″ for working pressure up to 200 lbs.

OTHER PRODUCTS

Tapping Valves
Mud Valves
Shear Gates
Flap Valves
Wall Castings
Floor Stands
Flanged Fittings
Flange and Flare Fittings
B & S Fittings
Cutting-In Tees
Valve Boxes
Special Castings

HYDRANT MAINTENANCE

By E. T. CRANCH

President and Manager, New Rochelle Water Co., New Rochelle, N. Y.

GOOD housekeeping is always essential. Women are judged by the manner in which they keep their homes—neatness, if you please. Neatness in water works operation should also be considered essential, and perhaps we should ask for the ladies' advice on our water works "housekeeping" more often than we do.

The Hydrant as a Symbol

Fire hydrants are, without doubt, the most conspicuous and most frequently commented on part of any water works plant. Yet too often these symbols of the water utility suffer from neglect. In the good old days when one could tour the country without worrying about gasoline and tires it was always refreshing to come to a town with bright, freshly painted hydrants, and these always stood out in sharp contrast to the many communities where the hydrants were drab and neglected. We in the water works fraternity should practice "good housekeeping" for our satisfaction as well as for the impression it makes on others.

Paying Procedure

Twice each year every fire hydrant should be given a routine inspection—once in the spring and once in the fall. This inspection should include a pressure test. This test is important for three reasons: it checks on the closing of the drip valve, it reveals any cracks which may have developed from either freezing or external damage, and it proves whether the nozzles are tight. When you first apply the pressure test, always stand back of the hydrant. We have seen serious injury caused by a nozzle flying off and striking a man in the stomach.

Outside of the condition of the hydrant, the pressure test also at times gives valuable information as to underground leaks. The pressure observed should always be compared with that recorded on previous tests. If there is any material reduction, the matter should be at once investigated. This method has sometimes given the first clue to locating serious underground leakage.

A dependable worker given a thoroughly equipped truck for hydrant and valve maintenance work represents money well spent

Importance of Lateral Valves And Their Maintenance

Every hydrant should be equipped with a gate valve on the lateral. This is essential to the efficient operation of any water works system. Otherwise a damaged hydrant may necessitate the shutting down of a considerable length of street main and the putting out of service of several other hydrants while repairs are being made to one. This might easily prove very embarrassing to a water department as well as a water company, especially if a hydrant is damaged during a large fire. If any municipality still has hydrants without a gate valve on the lateral we strongly recommend that such gate valves be installed at the first opportunity they can be obtained.

THE NEW ROCHELLE WATER CO.,
NEW ROCHELLE DIVISION
New Rochelle, N. Y. ..... 19.....

DAILY HYDRANT REPORT

No. of Hyd.	STREET	Press.	Time Taken	Greased	Packed	New Bolts	Painted	Numbered	Unusual Repairs

FORM 6 IM-4-37

Fig. 1.—Daily Hydrant Report Form Used for Recording Routine Maintenance Inspection and Repairs.

Report Records

Figure 1 is a form of daily report for work on hydrants which we have found very satisfactory. It will be noted that this form calls for "No. of Hyd." We have found it convenient to number all of our hydrants serially. This number is stenciled at the base of the hydrant on the side facing the street Figures about 2 inches high are used. It will be noted that following the pressure column ("Press.") there is a column "Time Taken." In comparing pressures it has been found helpful to know the time of day at which each pressure was taken. The next five columns are simply checked off as the operations are performed. In the last column any unusual repairs required are noted.

Painting Policy and Practice

We have found it good policy to paint all hydrants once a year. In this way the hydrants always have a well groomed look and are a credit to the company. If a high grade enamel paint is used, the hydrant may look quite passable for a period of two years, but at the end of two years it is difficult to apply a new coat of enamel satisfactorily without a lot of wire brushing on the old coat. We have found a semigloss paint to be most satisfactory. It holds up very well for a year and is easy to

B.P. 13640✱

NO.

LENGTH OF LATERAL ft. HIGHWAY ☐ PRIVATE ☐

DIAM. OF LATERAL in. CUTLETS

SMITH TAP ☐ REG. VALVE ☐

DISTANCE HYD. TO VALVE

DIAM. OF STREET MAIN in. HYD. BBL. SIZE in.

ELEVATION ft. DATE

REMARKS

DATE	PRESSURE AT INSPECTION	DATE	PRESSURE AT INSPECTION

DATE	HYDRANT		PIPE		VALVE SIZE	G.B. OR M.H.	WORK ORDER
	MAKE	VALVE SIZE	SIZE	LENGTH			

NO.

TYPIST PLEASE NOTE—THIS SCALE CORRESPONDS TO TYPEWRITER (PICA) SCALE—SET PAPER GUIDES SO THAT CARD SCALE WILL REGISTER WITH MACHINE SCALE WHEN CARD IS TURNED INTO WRITING POSITION. START INDEX THREE (3) POINTS FROM LEFT EDGE OF CARD. USE OTHER POINTS OF SCALE FOR OTHER DIVISIONS OF VISIBLE TITLE. SET TABULATORS TO INSURE PERFECT ALIGNMENT OF EACH DIVISION OF INFORMATION. FOLD BACK OR REMOVE STUB AFTER TYPING. USE NEW TYPEWRITER RIBBON.

KARDEX VISIBLE DIVISION 886-200-85814-'38 REMINGTON RAND INC.—13 Printed in U.S.A.

Fig. 2.—Permanent Maintenance Record Form of the Kardex System.
(Gives all essential operating information at a glance. Also provides the important continuing property record now increasingly demanded by State Public Service Commission.)

repaint. We have painted as many as 140 hydrants with one gallon of paint.

Immediately after a hydrant is painted, be sure a "wet paint" sign is securely fastened to the hydrant. It is surprising how much clothing can be damaged by brushing up against a freshly painted hydrant, and unless the wet paint sign is there, the water utility (company or department) will be faced with paying damages.

We have tried using a portable spray pump but have found it wasteful of paint and that we could paint just as many hydrants per day by hand.

Packing and Lubrication

For packing we use jute impregnated with tallow. This has proven very satisfactory. For lubrication we use a grease with a graphite base. We have tried various types of grease and the graphite base grease is the only one we have found which will not cause the caps to stick, especially in cold weather.

Cap Chains Useless Impedimenta

The common practice is to have the caps fastened by chains to the hydrant barrels. We found the fire departments in trying to get connected to a hydrant in a hurry were often greatly annoyed by the chain. We therefore tried the experiment some ten years ago of removing all the chains. We feared that caps might get lost or misplaced during a fire so we equipped each fire truck with an extra cap, but to date none of these extra caps have been used and the fire departments are greatly pleased with the elimination of the chains.

It is essential at all times to have the full cooperation of the fire department and arrangements should be made to have the fire department report to the water department after it has used any hydrant. The water department should then make a special inspection of this hydrant to see that everything about it is all right. The fire department should also be instructed never to force a hydrant in trying to close it. If it does not close readily, have the water department or company notified.

Continuing Records

Figure 2 illustrates a form of permanent hydrant record which is used in a Kardex file. This card gives all the essential operating information as well as that necessary for the maintenance of a continuing property record such as is required now by several Public Service Commissions.

TABLE OF EFFECTIVE FIRE STREAMS

Using 100 feet of 2½-in. ordinary best quality rubber-lined hose between nozzle and hydrant or pump.

Smooth Nozzle, Size	¾ Inch						⅞ inch					
Pressure at Hydrants, lbs.	32	43	54	65	75	86	34	46	57	69	80	
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70	
Press. lost 100′ 2½″ hose	2	3	4	5	5	6	4	6	7	9	10	
Vertical Height, feet	48	60	67	72	76	79	49	62	71	77	81	
Horizontal Distance, feet	37	44	50	54	58	62	42	49	55	61	66	
Gallons Discharged per min.	90	100	116	127	137	147	123	142	159	174	188	

Smooth Nozzle, Size	1 Inch						1⅛ Inch					
Pressure at Hydrant, lbs.	37	50	62	73	85	97	41	54	67	80	93	
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70	
Press. lost 100′ 2½″ hose	7	10	12	13	15	17	11	14	17	20	23	
Vertical Height, feet	51	64	73	79	85	89	52	65	75	83	88	
Horizontal Distance, feet	47	55	61	67	72	76	50	59	66	72	77	
Gallons Discharged per min.	161	186	208	228	246	263	206	238	266	291	314	

Smooth Nozzle, Size	1¼ Inch						1⅜ Inch					
Pressure at Hydrant, lbs.	46	60	75	90	104	119	52	69	86	102	119	
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70	
Press. lost per 100′ 2½″ hose	16	20	25	30	34	39	22	29	36	42	49	
Vertical Height, feet	53	67	77	85	91	95	55	69	79	87	92	
Horizontal Distance, feet	54	63	70	76	81	85	56	66	73	79	84	
Gallons Discharged per min.	253	292	326	357	386	413	307	354	396	434	469	

THE KENNEDY VALVE MFG. CO.

Main Office and Works: Elmira, N. Y.

WAREHOUSES

New York, 6th Ave. and Spring Street — Chicago, 1306-1312 South Canal Street — San Francisco, 448-450 Tenth Street

SALES OFFICES: New York, Philadelphia, Chicago, San Francisco, Cleveland, Salt Lake City, Seattle, Los Angeles

EXPORT OFFICE: 330 West 42nd Street, New York City

Kennedy Fire Hydrants and Water Gate Valves Conform with Specifications of the American Water Works Association

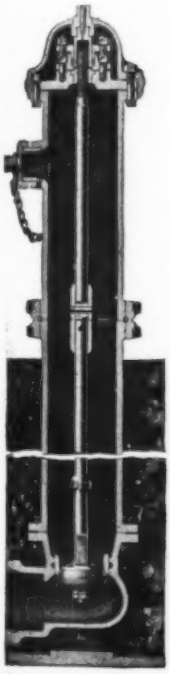
"SAFETOP" FIRE HYDRANTS

Distinguishing feature is the patented Safety Breakable Section. This section is fully as strong as the standpipe and stem of other hydrants on the market; but in case of a smashing impact it breaks cleanly apart, strictly localizing the damage to very inexpensive parts and protecting the occupants of the colliding vehicle from serious injuries. Over 100 demonstration and service tests have proven every claim made for this design.

The Safety Breakable Section consists of a standpipe breaking ring and a stem coupling, located a few inches above the ground level.

If broken, these parts may be renewed, and the hydrant put back into service, within half an hour, at a total cost of less than $10.00 for parts and labor, without shutting off water service.

Collision repair parts are furnished compactly boxed for convenience and safekeeping. The repair can be made by one man, with a few commonly used tools.



Additional Features

Simple, positive operation — centrally located straight line mechanism without levers, pins, or other complications.

Minimum friction loss — carefully proportioned elbow without depressions or pockets; inlet valve with net area greater than nominal size of hydrant; nozzles have bell entrances and carefully shaped interiors.

Extra-large standpipe — 7-in. dia. for 4-in. size; 8½-in. dia. for 5-in. and 6-in. sizes; smooth and free from obstructions.

Flood-proof—inlet valve closes in the direction of pressure from the main; therefore the water pressure alone keeps the valve tightly closed in case of accidental breakage of standpipe.

Frost-proof — double, positive-acting drain valve automatically opens when the inlet valve is closed, keeping the standpipe free from water.

Leak-proof, durable valves and gaskets —Balata inlet valve, best quality leather-faced double drain valve, special composition gaskets.

Convenience of adjustment—all operating parts readily accessible without excavation; hydrant readily altered for change of grade without shutting off the water pressure.

Protected from theft or tampering—all adjustable parts fully enclosed within the cover; nozzles screwed and pinned in standpipe.

Best material throughout—vital parts made of hard bronze; bronze stuffing box, nuts and rust-proofed studs; standpipe exceptionally heavy for resistance to impacts, and tested to 300 lb. hydrostatic pressure.

STANDARD FIRE HYDRANTS

This design is a one-piece hydrant with the same cover assembly, operating mechanism, inlet and drain valves as in the SAFETOP Hydrant, and the same additional features as listed in the preceding column.

Many hundreds of thousands of these hydrants are in use all over the country. They have the same sturdy construction, simple positive operation, and attractive appearance as the SAFETOP Hydrant, but the standpipe and stem are in one piece.

WATER GATE VALVES

Made in sizes of 3 to 60-inch, designed for water working pressures of from 15 to 150 lb., and furnished for manual, gear, electric motor or cylinder control.

These valves will operate horizontally, upright or at an angle. The wedging mechanism, consisting of two wedges and two hooks, is actuated from stops cast in the valve body. In closing, the parallel discs and seat faces move so closely upon each other that foreign matter is scraped off. At the instant of closing, the discs are exactly opposite their ports and are forced by the wedges against their seats. In opening, the action is reversed. The discs are released by the first stem movement, and further stem movement completes the operation with an ease not obtainable with other types of valves.

Either disc may be toward the pressure. Large-size valves for horizontal operation have their discs equipped with rollers traveling on tracks to reduce friction, and have scrapers to keep these tracks clean.

OTHER KENNEDY PRODUCTS

Gate, globe, angle and check valves in iron-body, bronze, and special metal, for low, standard, medium, extra heavy and high pressures, and in a wide range of sizes for steam, water, air, oil and chemical pipe line service.

Hose gates, check valves, indicator post gate valves and sprinkler valves approved by the Board of Underwriters for fire protection.

Complete lines of standard cast-iron flanged fittings, malleable-iron and brass screwed pipe fittings, and standard and extra-heavy cast-iron flanges.

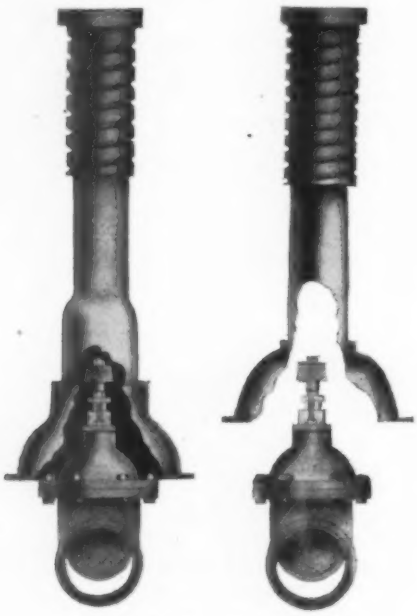
GATE VALVE CARE AND MAINTENANCE

By ROGER W. ESTY

Superintendent, Water and Sewer Board, Danvers, Mass.

TOO commonly, one of the most neglected of the routine operations in a water works system is the care and maintenance of gate valves. In some of the larger cities there are maintenance crews created particularly for this type of work. The crew is generally made up of some of the older men who are experienced in this work, due to their long service with the department or the water company.

They are furnished with a truck equipped with all the necessary tools, wrenches and spare parts, and they may also have built into the truck a mechanical operating device to open and close the gate valves. Smaller towns are more often than not unable to give proper attention to their gates, due primarily to lack of sufficient man-power to do this work and carry on the many other essential activities common to a water works plant.



Valve Box Settings

On the left is a setting as it is pictured in catalogs, and generally installed. To my way of thinking, the method of putting the valve nut-up in the contracted section is improper. On the right is a suggested better way for the several reasons cited in the text. Possibly this may suggest an advantage to be gained in an improved design of this type of box to give better overall service.

My water works experience goes back over a period of 27 years. During that time I have located, measured and plotted onto cards and maps every hydrant, gate valve, and all of the pipe in our system. I have opened and closed every gate valve many times. It was 20 years ago that we first had a water waste survey made of our system and, as many know, this necessitates the opening and closing of essentially every gate valve in the system. This type of work we have continued every second year since, which affords added opportunities of locating and operating all of our gate valves.

Main Flushing Reveals Gate Valve Conditions

Occasionally our piping system is entirely flushed out, street by street, and this again means the operating of nearly every gate valve, and some have to be opened and closed several times during this flushing operation if properly conducted.

From this work experience is gained in the knowledge of what to expect of gate valves and the remedies that are used in perfecting their operation.

Stiff Operation a Main Trouble

One of the main difficulties, if not the main difficulty, we find with gate valves is that they turn hard. As years go on, if such valves are not operated occasionally they become more difficult to operate and in some cities and towns it takes two men, or even as many as four and six men, to close down a gate valve even during a testing period.

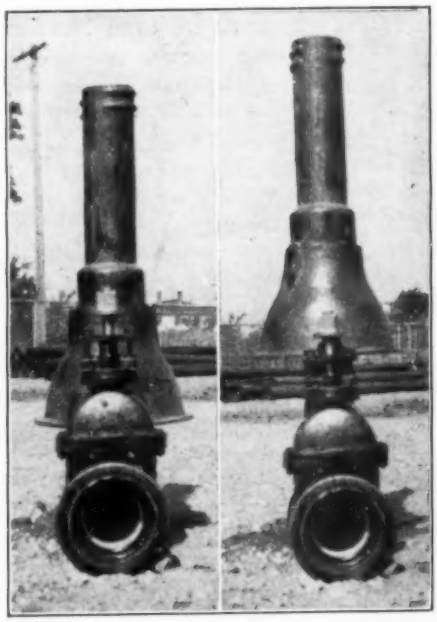
My experience does not go beyond a 20-inch gate valve, but it seems to me that the same principles and characteristics are applicable to all sizes.

A great deal of the indifference toward gate maintenance can be traced to the swivel chair operator. By that I mean the man in charge of the water works who has never experienced the opening and closing of all of the gate valves in his system. If he made tests of his system, such as a water waste survey, and had to work all night opening and closing these gate valves himself, he would soon issue an order to do something about making them operate easier. But generally, it is below his dignity to leave his swivel chair to do this type of work, to find out first hand the physical condition of his system. He doesn't care; he doesn't have to operate them; let the men do it, even if it does take two, four or six to do the job.

The Remedy

What are the difficulties we encounter; what causes them, and how can they be remedied? Why should it take four men to close a gate valve when one man should do it?

Why do stems get bent and broken? What is the cause of all this? Is it because the mechanism is not correct in design, or that the mechanism is not made heavy enough? I feel that the manufacturers as a general rule put on the market a gate valve that will meet all reasonable conditions according to our water works standard specifications. However, I do think the manufacturers do lose sight of one very important factor, and that factor is the packing, and in my opinion, if improper or



A photographic attempt to indicate the advantage of setting the box bonnet higher, giving more clearance between box walls and nut and stem of the valve. The usual setting (left) is in truth a "rock trap," while the other permits rocks to pass by; also makes for easier key connection with the nut should the box become off-center.

neglected packing is not the direct cause, it is at least the seat of 90 per cent of all gate valve troubles.

Many ask, why does the packing have such an important bearing on the ease of operation of the gate valve? Well, the packing gets dry and hard as the years go on. This dry packing acts as a brake on the valve stem.

Take, for instance, your automobile—the brake linings are dry and the brake drum of the wheel is smooth and dry. When the pressure is exerted against one another it creates friction, and

Danvers' Alemite Lubricating Outfit Servicing a Geared Valve.

this friction creates your braking or stopping power. Sometimes at high speeds this friction actually locks the wheels and causes fatal accidents.

On the other hand, pack the brake drums with grease and then attempt to stop your car. The grease eliminates the friction, therefore there is no friction created to stop your car.

Take a rope and wind it around an inch pipe three or four times and draw it tight and then attempt to turn the pipe. You will find you can't do it. Then grease the rope thoroughly and you will find that you can turn the pipe very easily. Try it for your own satisfaction.

Did you ever try holding an eel in your hand? If you have, you probably found that it was nearly impossible to hold it because it was so slippery. If you can get your gate valve stem and packing in the slippery condition you find the eel, you'll have no more hard turning gate valves.

However, there is a difference in the mechanism in some of the gate valves and one make may operate a little different than another make when new. But on the whole, modern gate valves should operate more or less in the same easy manner.

A Case of Proof

Several years ago, while making a water waste survey during nights, we came across a 12-inch gate most difficult to operate. It took the combined efforts of two of us to open and close the gate. The next day I had the gate dug up and repacked. It seems hardly believable, but it could then be turned with just one finger against the cross-bar of the gate key.

Such ease of operation surely saves breaking or bending the valve stems and makes the operation of the gate a pleasure instead of a dreaded job.

Some Packing Pointers

On many of our gate valves and nearly all of our hydrants we have removed the original braided packing and inserted a metallic plastic packing, with two or three strands of flax string type packing on top to keep it from squeezing out when the packing gland is tightened down.

After taking out all of the braided packing, we squirt down around the stem near the packing plate some kerosene or light lubricating oil. We then fill up the stuffing box with a metallic packing that comes in a loose plastic form or in string form. We then put on the stuffing box follower and tighten it down. We then open and close the valve a few turns and then tighten it some more. If it needs a little more packing we insert some and go through the operation again. This method has solved our packing problems and made hard turning gate valves easy turning, and makes fun out of a disagreeable job.

The Larger Valves

In the large gates we drill a hole through the packing plate and insert an alemite fitting. These gate valves still have the braided packing in the packing box. By connecting a grease gun to this fitting we can apply by means of our air compressor about 3,500 pounds pressure and this forces the grease in and around the stem and packing and does a very satisfactory job of lubricating.

It does such a good job on these gate valves that it is a monotonous one man job of opening and closing the valve when testing; in fact, a boy 10 years old can operate the valve.

Large gate valves should have an ample size manhole constructed around them so that a man can get down to the gate and repack it. Smaller gates can be handled more economically by using a 5¼ or 7-inch valve box over the gate with the cover flush with the road.

The gears of a geared gate should be enclosed in a housing with the gears running in oil. If the gears are not housed then they will collect rust and dirt in between the gears or teeth,

Danvers' Method of Marking Street Gate Locations.
Yellow figures stenciled on black field on nearest pole.

making them fit tight and bind, causing the gate to operate hard. Dirt falling down into the hole when the cover is picked up causes some of this trouble.

We have eleven 20-inch open geared gates and we wish we had purchased the oil enclosed style. That surely was an error on our part, but our experience with them has taught us to advise others to buy the oil enclosed style.

We have constructed a shield that fits over the gears and the operating nut and fastens to the bolts holding the stuffing box to the bonnet of the gate. This has proved very satisfactory and the dirt does not get into the gears. This gives us the opportunity to keep them well greased.

Improper Valve Box Setting

Many gate valve catalogues show what, in my opinion and experience, is an improper method of setting the box over the gate. Pick up any catalogue and turn to the gate box section

showing the 5¼ or 7-inch box. You will notice that the base or pot sets down over the top of the gate so that the base of the box is even with the flange in the center of the gate. Then the upper section, or middle section, is set onto the base, leaving the operating nut up in this section.

My contention of it being an improper setting and causing maintenance troubles is that if rocks do get into the boxes (and the kids sure do put them in sometimes), that the rock cannot go down past the operating nut. It gets wedged in so hard sometimes that it is impossible to get the key onto the operating nut, and if you do, you cannot turn it. If the box is pushed to one side slightly, the box then comes up against the operating nut and prevents putting the gate key onto the operating nut.

If, on the other hand, the base or pot is set so that the base is up at the level of the stuffing box plate, rocks then can roll to one side into the base, and if the box is tipped there is a greater possibility of getting the gate key onto the operating nut.

In my opinion, box setting is a very important part of your gate maintenance work.

Location Records

Location plans of gate valves should be carefully prepared and measurements should be taken from permanent benches, such as to other gate valves, hydrants, catch basin grates, manhole covers, curbs, etc., and not from telephone poles, trees, walls, fences, etc.

These measurements should be on cards and on sheets in bound books for quick reference. Each should have a number and these can be painted on the underneath side of the valve box cover if desired.

Stencilling of measurements onto buildings, poles, etc., are helpful for quick locating. Numbers can be nailed onto poles or buildings that will stay on as long as the pole or building remains in place. We paint a black square on the reference object and nail on the metal numbers that have been sprayed with an orange colored paint. The contrast makes it conspicuous from any other type of marking.

Removing Recalcitrant Box Covers

Sometimes the gate box cover gets sealed in with tar, or in the winter is frozen in. This can be very easily overcome by pouring a little gasoline on it and setting it on fire. In a few moments the cover can be easily removed.

Quite often it is found difficult to close the gate tightly. This is generally caused by tuberculation in the valve guides and seat. By opening and closing several times this incrustation breaks off and the velocity of the water between the gate and the seat of the valve will most always flush out, allowing the gates to eventually properly seat and closing off entirely the flow of water.

Gate valve work is not expensive. It is a tedious job but can be made very interesting by the various things that have to be done, such as checking measurements, marking poles or buildings, opening and closing, repacking, and the resetting of the gate box at higher elevation.

If a few of these suggestions are followed, most of your gate valve worries will be a thing of the past:

Good plans and measurements.

Stencilled or metallic reference numbers on poles, buildings, etc.

Gate box covers flush with the surface of the ground.

The base of the box well above the center flange of the valve.

Opening and closing each valve on a yearly schedule.

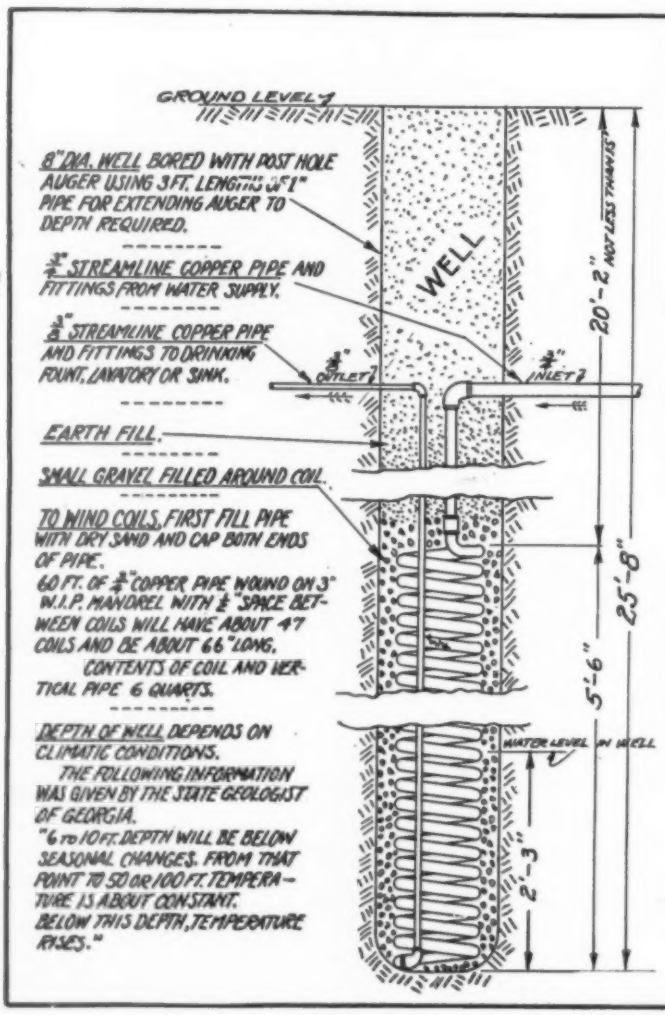
Last, and the most important, proper packing and lubrication.

And a good motto is:

"More turning of gate stems and less of swivel chair stems."

"Know your gate valves!"

UNDERGROUND WATER COOLING SCHEME OF ATLANTA WATER DEPARTMENT


GROUND LEVEL
8" DIA. WELL BORED WITH POST HOLE AUGER USING 3 FT. LENGTHS OF 1" PIPE FOR EXTENDING AUGER TO DEPTH REQUIRED.
¾" STREAMLINE COPPER PIPE AND FITTINGS FROM WATER SUPPLY.
¾" STREAMLINE COPPER PIPE AND FITTINGS TO DRINKING FOUNT, LAVATORY OR SINK.
EARTH FILL.
SMALL GRAVEL FILLED AROUND COIL.
TO WIND COILS, FIRST FILL PIPE WITH DRY SAND AND CAP BOTH ENDS OF PIPE.
60 FT. OF ¾" COPPER PIPE WOUND ON 3" W.I.P. MANDREL WITH ¾" SPACE BETWEEN COILS WILL HAVE ABOUT 47 COILS AND BE ABOUT 66" LONG.
CONTENTS OF COIL AND VERTICAL PIPE 6 QUARTS.
DEPTH OF WELL DEPENDS ON CLIMATIC CONDITIONS.
THE FOLLOWING INFORMATION WAS GIVEN BY THE STATE GEOLOGIST OF GEORGIA.
"6 TO 10 FT. DEPTH WILL BE BELOW SEASONAL CHANGES. FROM THAT POINT TO 50 OR 100 FT. TEMPERATURE IS ABOUT CONSTANT. BELOW THIS DEPTH, TEMPERATURE RISES."
WELL
OUTLET
INLET
20'-2" NOT LESS THAN
25'-8"
5'-6"
WATER LEVEL IN WELL
2'-3"

COIL WELL AT PIPE YARD ATLANTA WATER WORKS — DEPTH OF WELL..... 25'-8" DEPTH OF WATER IN WELL..... 1'-0"		AIR TEMPERATURE AT SURFACE	TAP WATER TEMPERATURE	COIL WATER TEMPERATURE	AIR TEMPERATURE AT 15 FT. DEPTH	WATER TEMP. AT BOTTOM OF WELL	
7-19-34	9:00 AM	87°F.					
7-19-34	11:00 AM	89°F.			66°F.		
7-19-34	1:00 PM	77°F. RAINING				65°F.	
7-23-34	11:00 AM	91°F.	87°F.	66°F.			
7-24-34	2:00 PM	93°F.	87°F.	66°F.			
8-23-34	1:00 PM	88.5°F.	83.5°F.	66.0°F.			
4" DIA. OPEN WELL AT DWELLING ON TRABERT ROAD — DEPTH OF WELL..... 29'-0" DEPTH, WATER IN WELL..... 1'-0"							
10-2-34	10:30 AM.	82°F.			65°F.	64°F.	

THE FOREGOING DATA SECURED BY L.W. DE JARNETTE, CHEMIST OF ATLANTA WATER WORKS USING A.S.T.M. TYCOS THERMOMETER No. 971872.

NEWS ITEM — "THE SHAFTS IN ROBINSON DEEP IN THE WITWATERSAND (WHITE WATER RIDGE), SOUTH AFRICA GOLD MINE, REACH A DEPTH OF 8,380 FT., THE GREATEST DEPTH TO WHICH MAN HAS EVER DESCENDED. TEMPERATURES RANGE FROM 100 TO 120°F. RISE IN TEMPERATURE DUE TO ATMOSPHERIC PRESSURE IS 5 DEGREES FOR EVERY 1,000 FT. OF DEPTH."

CONCLUSION

DRINKING WATER THE TEMPERATURE OF LOCAL WELL WATER CAN BE OBTAINED WHEREVER WATER UNDER PRESSURE IS AVAILABLE. ALL PIPING INCLUDING COIL BEING OF COPPER, THERE WILL BE NO CORROSION AND THE PIPE WILL LAST INDEFINITELY.

UNDERGROUND WATER COOLING COILS
AS INSTALLED BY ATLANTA WATER WORKS
AT HEMPHILL PUMPING STA. PIPE YARD

DESIGNED BY W.M. RAPP, SUPT.
DEPT. OF CONST. & DIST.
ATLANTA WATER WORKS
ATLANTA..... GEORGIA

SCALE:- 1½" = 1'-0" OCT. 5, 1934

S-75

SCHRAMM, INC.

PORTABLE AND STATIONARY

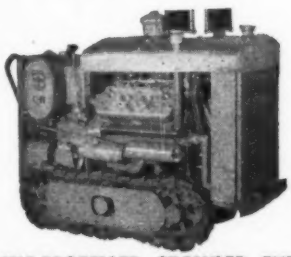
AIR COMPRESSORS

Main Office and Factory - WEST CHESTER, PA., U. S. A.

SALES OFFICES AND REPRESENTATIVES

ATLANTA, GA.....273 Capital Avenue, S. W.
BALTIMORE, MARYLAND.....530 E. 25th Street
BOISE, IDAHO.....Broadway at Myrtle
BOSTON, MASS. (Newton Highlands) 130 Needham St.
BUFFALO, NEW YORK.....101 Great Arrow Road
CHICAGO, ILL.....2020 W. Walnut Street
CLARKSBURG, W. VA.....212 Ohio Avenue
DALLAS, TEXAS.....1300 McKinney Ave.
DENVER, COLO.....Sixth & Acoma Streets
DETROIT, MICH.....6331 Tireman Avenue
INDIANAPOLIS, IND.....1900 Northwestern Avenue
KNOXVILLE, TENN. .....408 Davenport Road
LITTLE ROCK, ARK.....115 N. Spring Street
LOS ANGELES, CALIFORNIA.820 S. Santa Fe Ave.
MEMPHIS, TENN.....269 S. Front Street
MIAMI, FLORIDA.....1228 S. W. 1st St.
MILWAUKEE, WISC.....4603 West Mitchell Street
MINNEAPOLIS, MINN.....514-520 Second St., S. E.
NASHVILLE, TENN.....309 Seventh Ave., S.
NEW HAVEN, CONN.....1881 Dixwell Avenue
NEW YORK CITY, NEW YORK.....90 West Street
OMAHA, NEBR.....1516 Leavenworth Street
PHILADELPHIA, PA.....3719 Filbert Street
PHOENIX, ARIZONA.....P. O. Box 3615
PITTSBURGH, PA.....512 Columbia Building
PORTLAND, MAINE.....803 Forest Ave.
PORTLAND, OREGON.....1233 N. W. 12th Avenue
PROVIDENCE, R. I.....750 Reservoir Avenue
RICHMOND, VA.....12 N. 15th Street
SAN FRANCISCO, CALIF.....Folsom at 17th Street
SEATTLE, WASHINGTON...1520 Fourth Ave., South
ST. LOUIS, MO.....1325 Macklind Ave.
WASHINGTON, D. C.....1254 23rd St., N. W.

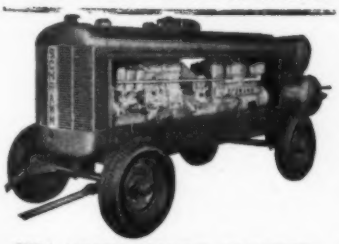
TWO WHEEL TRAILER



SELF-PROPELLED CRAWLER TYPE

DELUXE WITH TOOL BOXES AND HOSE REELS

SKIDDED FOR TRUCK MOUNTING



FULL DIESEL ENGINE POWERED

PORTABLE COMPRESSORS—All SCHRAMM Compressors are intended for heavy-duty, continuous service with minimum attention. They are suitable for service twenty-four hours per day and will perform such service with lowest up-keep and operating costs. The purpose of this page, therefore, is to present the standard types of SCHRAMM Compressors. Descriptions and data are necessarily brief but complete specifications and other information will be gladly furnished upon further request by any of the agencies listed above.

TWO WHEEL TRAILER TYPE MOUNTING: A model that can be very easily coupled to car or truck and hauled at towing speed.

SELF-PROPELLED CRAWLER TYPE: A complete No. 60 Crawler type compressor mechanically operated under its own power.

DELUXE WITH TOOL BOXES AND HOSE REELS: Provided with a universal trailer coupling or towing ring for connection to car or truck, for hauling at maximum towing speeds.

SKIDDED FOR TRUCK MOUNTING: Can be easily loaded on a motor truck body for temporary use or for transportation.

FULL DIESEL ENGINE POWERED: Cuts fuel costs and contributes to better performance and longer life.

STATIONARY COMPRESSORS: "V" OR FLAT BELT DRIVE: They can be had with "V" or flat belt pulley, or without pulley, with and without cooling unit, or base.

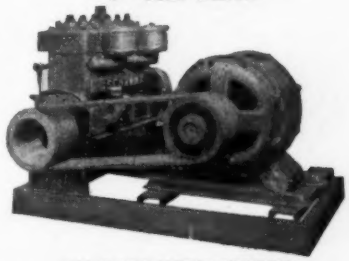
ON BASE WITH MOTOR: Belt drive assemblies are available for operation at standard speed or, at less than standard speed or where it is desirable to use a motor or engine of different speed.

DIRECT "BUILT-IN" MOTOR DRIVE: Compressor and motor are assembled rigidly and in perfect alignment, and are mounted on a substantial steel type, closed base.

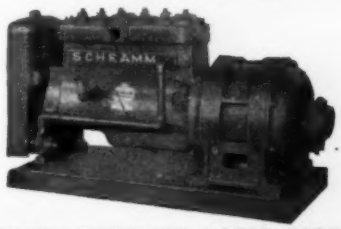
ENGINE DRIVE STATIONARY—IN-LINE—SCHRAMM Engine Driven Stationary units are made available for those applications not reached by electric power service or where gasoline, oil, distillate or diesel power units are preferred.

ENGINE BELT DRIVE ON BASE: Combinations of this type are assembled with compressor and power unit mounted on a steel frame, with "V" belt drive, a very compact and complete combination.

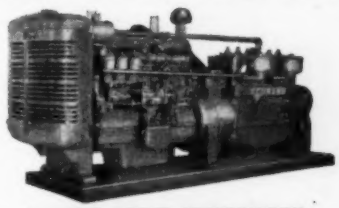
"V" BELT DRIVE



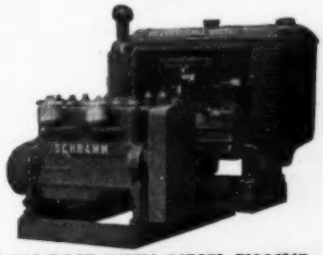
ON BASE WITH MOTOR



DIRECT "BUILT-IN" MOTOR DRIVE



ENGINE DRIVE STATIONARY IN-LINE



ON BASE WITH DIESEL ENGINE

DE-WATERING MAINS WITH COMPRESSED AIR

Eliminates Pumping, Wet Trench, Loss of Time

By ARTHUR C. KING

Superintendent of Water Works, Taunton, Mass.

IN THE 1939 Reference Data Issue of "WATER WORKS AND SEWERAGE" an article by Roger W. Esty and Nelson Boardman of Danvers, Mass., describes the use of compressed air for removing water from mains.

Here in Taunton, Mass., we have adopted the method, developed by Esty and Boardman, and have successfully used it on pipe of such size that we believe our experience might be of interest to others who may have questioned the value of the scheme for mains of larger sizes. (See sketches on next page.)

An Experience with a 12-Inch Main

It became necessary to relocate about 600 feet of 12" cast iron main. Since occupied buildings were supplied from the section to be relocated, it was decided to lay the new main before cutting off the old for salvage.

After the new pipe was laid, the problem was that of making the connections between the old and new as quickly as possible, both on account of regular use and also the reduction in fire protection during the change-over. The section to be drained (about 2500 ft.), lay on an up-grade, as will be seen on the accompanying sketch (a), and hydrants were already in place at the high end and near the low end. The main was shut down, the hydrant near the low end was opened, and the air compressor connected to the hydrant *at the high end*. In a surprisingly short time, perhaps 40 minutes, although it was not timed, water ceased to come out of the hydrant and the main was cut. No water came out through the cut. The old and new sections were connected and the water turned into part of the new main within 4 hours, restoring service to all buildings. The upper end was then cut off and reconnected. Not a bit of ditch pumping was required.

We Try a 16-inch Main

Another large main de-watered with compressed air was of 16" cast iron. The length between gates was about 1200 feet—see sketch (b). About 800 feet was on a slight up-grade to a summit, where there was a hydrant. The other 400 feet was on a downgrade to the point of cutting, with a hydrant in that shut-down section just beyond the cut. The low hydrant was opened and the compressor connected to the hydrant at the summit. The water was quickly driven out and the cut made. In this case, apparently some gate was not shut quite tight as a trickle of water occasionally came out, but it was not enough to make trouble for us. We considered this job also a remarkable demonstration of the Danvers method.

On second thought, another hydrant might have been opened to de-water part of the main on the slope back from the summit away from the work, before the cut was made. Then the leakage would have accumulated back of the summit.

We Do a 20-inch Job

On another occasion we used the air to empty about 700 feet of 20" cast iron pipe, sketch (c). The upper end was nearly level for about 200 feet then the pipe sloped down from a hydrant at the summit about 500 feet past the work to be done to a hydrant at the low end. Here again no difficulty was experienced and the water was driven out very quickly, but was not timed.

We also drained about 1200 feet of 12" cast iron shown on sketch (d). In this case we cut out and replaced an 8" gate valve on a branch main a few feet away, and on an up-grade, from the 12" main. The whole job of de-watering, cutting out the old and inserting the new gate, was completed in less than 2 hours.

Our compressor is set for a maximum of 95 pounds pressure and starts up when the pressure drops about 10 pounds. We did not note what pressure was held during de-watering, but there was no indication of lack of air or pressure for these lengths of 12", 16" and 20" mains. The rated capacity of our compressor is 110 cubic feet per minute.

The scheme proved its worth very effectively.

IMPROVED METHOD OF MAKING WET TAPS

By E. T. CRANCH

Manager, New Rochelle (N. Y.) Water Co.

It is assumed that all waterworks men are familiar with the ordinary hand operated machines for the making of wet-taps.

The hand operated machine, while a great convenience was, however, tedious to operate. A six or eight inch tap would take two or three hours to cut and the larger taps much longer. It would also take not less than three men, working in relays, to operate the machine successfully.

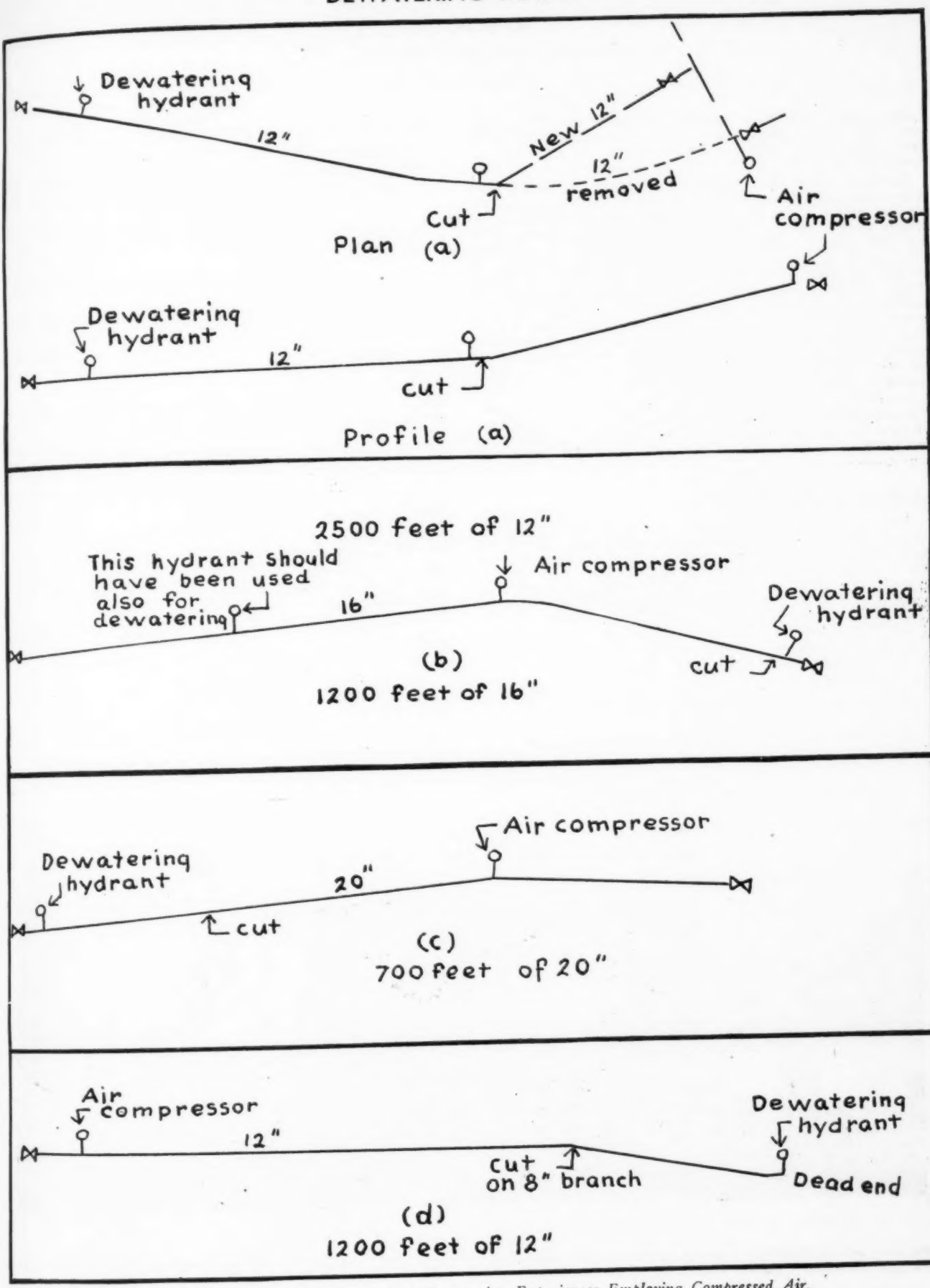
For plants which carry an air compressor unit in their equipment, there is now a means for making these taps quickly and easily. The old hand-type machine can be readily equipped with a bracket to permit the use of a compressed air motor and with a three-horse air motor an eight inch tap can be made in less than half an hour. With this arrangement it is also possible for one man to operate both the motor and the drill feed.

Equipping the machine with the motor-drive does not interfere with its continued use as a hand machine whenever conditions warrant, or should compressed air not be available at some time. It is only necessary to unscrew four stud bolts and remove the motor bracket. The machine is then ready for hand operation as before.

With the use of the air operated tapping machine we have recently made an 8-inch connection to a 12-inch main of class "B" pipe. In timing the whole operation it took just 90 minutes from the time the men started to place the sleeve on the pipe until the job was completed and the machine removed. The actual drilling time was, in this case, only 11 minutes.

The accompanying illustration is a picture made on an earlier job. The tapping machine, which is not new, was purchased some years ago from the A. P. Smith Mfg. Co. The compressed-air motor was supplied by Ingersoll-Rand Co.

DEWATERING MAINS



Sketches Revealing Conditions in Main-Dewatering Experiences Employing Compressed Air.

BLOWING OUT SERVICE LINES

By S. H. DAVIS

Superintendent, Benwood & McMechen Water Co.
Benwood, W. Va.

Most every water works operator will agree that a low pressure complaint can cause a water company to have poor, or at least "razor-edged," public relations between the affected customer and the company.

However, unless the condition is caused by insufficient main line capacity, the consumer's line, as well as the company's service line, is usually the cause of the low pressure complaint. Attempts to convince the affected customer that he should renew his lines usually brings the following question or statement: "Suppose I do renew my lines, maybe your line is stopped up between the main line and my property. How about you people doing a little digging first?" To answer that question to his satisfaction, usually means to remove meter, if located at property line or curb plot, or cut service line at curb-stop, and let him see for himself. If the pressure is poor and he sees it, he becomes very positive that he won't spend a dime until given better water pressure. He thinks it is high time that the water company correct that condition and he wants it done *"right now."*

Naturally, anyone responsible for the operation of a water company wants the customers satisfied, but on the other hand, he hates to dig into a paved street to disconnect a service from the corporation, or to renew the service line to satisfy the customer.

Method of Cleaning

We have had the usual number of low pressure complaints with all the grief that goes with them. We have tried various methods of cleaning out service lines and the method we now use is the compressed air and rock salt method.

The equipment consists of the following parts:

(1) Cylinder of compressed air—*don't use oxygen.*
(2) 15 ft. (2,000-lb.) wire braided hose with suitable connections to connect to service line.
(3) 1 (2,000-lb working pressure) check valve.
(4) 1 (2,000-lb.) working pressure) forged cross tee.
(5) 1 (2,000-lb. working pressure) angle valve—wheel type.
(6) 1 (1,000-lb.) relief valve—set at 600 to 800 lbs.
(7) 1 (1,800-lb.) pressure gauge.
(8) Necessary nipples to connect fittings and for connections on air cylinder (use extra heavy nipples).

The method of blowing out service lines is as follows:

(1) Make necessary test for low pressure.
(2) Fill wire braided hose with about 2 ft. of coarse rock salt (ice cream salt) and connect to service line with curb or meter stop in the off position.
(3) Close angle valve on tank connection—hose.
(4) Open curb or meter stop.
(5) Just crack needle valve on compressed air tank and then close *quickly* with one hand.
(6) Open angle valve *immediately* with other hand—the "shot" is fired.
(7) Allow muddy water from service to blow through angle valve until water is clear.
(8) Connect up line.

It is advisable to "crack" a nearby fire plug so that the excess air will go out through plug.

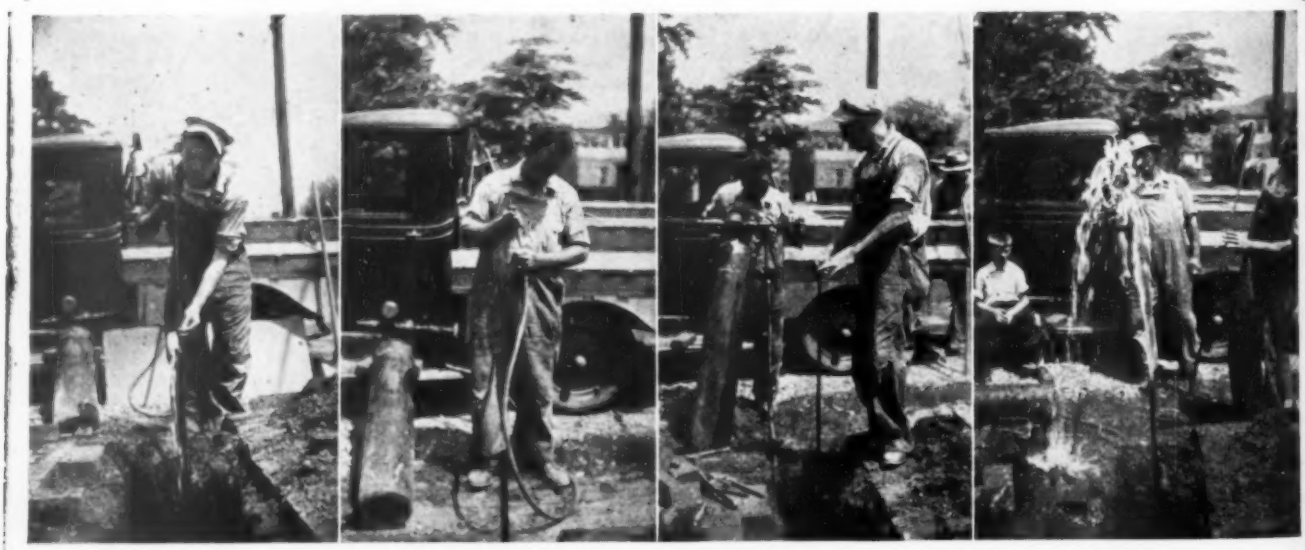
The action of the compressed air is very quick and a surging will be noticed in the armored wire hose, but after a few seconds the surging will stop and the water will flow out of the angle valve with normal pressure. As the rock salt enters the service line it literally scrapes the incrustation away from the line and the rock salt dissolves in the main line. No complaint of salty taste in the water has resulted, however.

This system is only recommended where lead or copper service lines have been installed. There is too much danger of rupturing a weakened steel line which is badly corroded.

The photographs show the results of this method. The height of water above ½-inch riser pipe (30 in. above curb stop) was 3 in. only. But, after blowing out service line the height of water was 36 in., indicating increased pressure and volume obtained.

We have found that after we do our part, should the pressure continue low, consumers become convinced that their piping is either corroded or too small. In most cases they will remedy their condition. We do not blow service lines from cellar to property line, because we feel that is the plumber's job.

The average time required to attach the equipment and blow out a service line is only 15 minutes. Our cost for a cylinder of air is approximately $2.50.



Dribble *Load* *Shoot* *Gush*

One That Needs Blowing; Loading Armored Hose with 2 ft. of Rock Salt; the Quick Shot of Compressed Air (Note Man with One Hand on Cylinder Valve, the Other on Release Angle Valve). Results—Plenty of Water and a Satisfied Customer.

SERVICE SHOOTING

By LA VERNE TRENTLAGE

Assistant Superintendent, Water Department, Elgin, Ill.

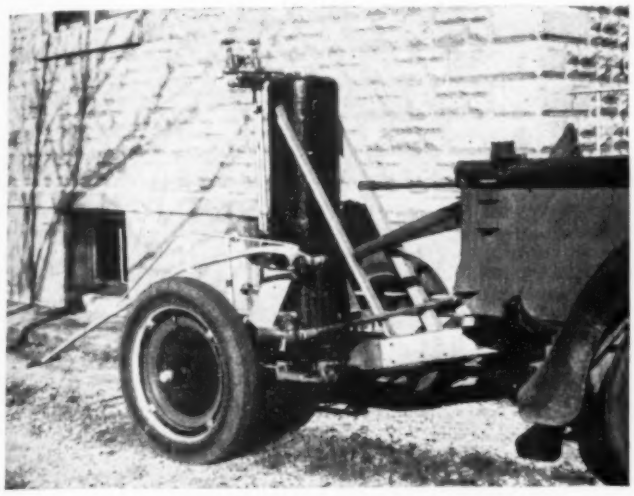
IN THE West Section of Elgin the well water supply was very hard and corrosive.

After many years of gradual build-up, hundreds of services became "plugged." As a department we did not have to look for these, for when this time arrived and consumers realized they had practically no volume, they would enter the Water Office and say, "We have no pressure—can hardly get any water."

In scores of complaints it was revealed that it was impossible to get water on the second floor, especially when water was being drawn on the ground floor. One who has never experienced this annoying trouble simply cannot appreciate their plight.

The average services, as mentioned, do not deliver more than 1 G.P.M. with our normal main pressure of 50 pounds behind it.

There is no doubt in my mind but thousands of small residential services are being replaced annually due to this corrosive condition. However, since we now know what we can do to restore much of the original volume, we feel obligated to the consumer to help him. We do this job of clearing the service



The Elgin "Blow-Tank."

line gratis because we are serving the public as a non-profit institution. Of course, it would be the simplest thing to say to this particular group of sufferers, "We are very sorry, but you will need a new service." To date we only use that statement after we *know* we cannot help them.

Step by Step Procedure

Our method of procedure to correct this fault is as follows:

1. First, a check is made to make certain of no break in the service line itself. If O. K., then:

2. A 2-gallon can is filled from the cold water faucet in the kitchen and the 'time" to fill is taken by a stop watch and recorded.

3. Immediately after, we take an ordinary ¾-inch garden hose, with the nozzle on, to learn the farthest point the water can be delivered. Then with the nozzle off we learn the farthest point the water can be delivered. We make this type of test to gain some technical but concrete figures for the record. Also the consumer can readily see what has been accomplished when the job is completed.

4. The blow tank is then hooked up and we're off. (How the blow is made follows later.)

5. After completing the job, points 2 and 3 (above) are followed up in the same way for the sake of comparisons.

Pertinent Facts

Now, and very briefly, we shall bring out some interesting facts drawn from our experience in "blowing."

1. Each "shot" discharged from tank into service is a mixture of air and water under 1,400 pounds of pressure—released by a quick opening valve.

2. The 1,400 pounds is necessary to obtain the excellent results that we get.

3. In very obstinate cases we also dig up at the curb box, connect on the tank, then blow out to main. Results? Very staisfactory.

4. Only one service in a hundred is ruptured in the shooting.

5. It is advisable to blow only single lines—not forked.

6. Services up through 1 inch can effectively be "blown."

7. Consumer signs a release, which protects the Water Department in event any pipes or the service are damaged.

8. Time required to make the blow—one hour. (Three men best for the job.)

9. Seven out of ten services are effectively cleaned out by the blowing method.

It is the kitchen faucet or sprinkling that usually tell the consumer about the poor volume. We all agree that when we want water we want it right now, in big volume and plenty of pressure.

We attack this problem in two ways: (1) Technical and (2) Practical.

For instance:

Before blowing we learn that it requires two minutes to fill a two-gallon can at kitchen sink.

After blowing we learn that it requires only 20 seconds to fill the same can—timed. These facts are entered on a record card.

Before blowing, outside, we learn that a nozzled hose will force water only 10 feet. (Without nozzle, ¼ to 2 inches only.)

After blowing, between 40 and 50 feet with nozzle, and from 9 to 22 inches without nozzle. These, of course, are measured figures.

The average housewife is not concerned about minutes, seconds, or measured distances "technically." Only "practically" is she satisfied with bigger volume, more pressure, and ability to sprinkle her neighbor or wet down the shingles on the roof is present.

Some Added Revenue Results

As a sidelight on this subject, it was learned from a detailed study of 100 services that the consumption per address per quarter increased only an average of 5,250 gallons, or an increase in the water bill of $1.50 per quarter.

The Department's reaction was neither disappointment nor surprise, for our chief concern was to satisfy the consumer by increasing the volume of water at the "Time and Location" demanded.

Parallel in importance to the results obtained by blowing is the financial side from the consumer's angle. For instance—

If we were not able to help the situation, the consumer would have to invest $35.00 or more for a new service.

This expenditure they already visioned, and as a result they all are very appreciative of our efforts. Therefore, we know that:

"A FRIEND IS MADE EVERY TIME A SERVICE IS SAVED."

Since our water has been softened and filtered, the number of poor pressure complaints has fallen off 80 per cent and we anticipate a further reduction again this year.

Blowing Operations

In closing, I want to give a brief description of the direct method employed.

The blow-tank stands outside The meter is disconnected and the tank hose connected where the meter was. The shortest length of hose possible is used.

The tank of atmospheric air is allowed to fill up to "Main Pressure" with water from the mains. From this point, and on up to 1,400 pounds, the pressure is developed by means of an hydraulic pump (single piston) operated manually. When 1,400 pounds is reached, the "shot" is discharged by means of a quick-opening lubricated valve.

A small gate valve is then opened after each shot, to allow the fresh water from the "main" to push out the "disturbed"

water in the service back to, but by-passed from tank so it will discharge onto the ground.

After every "shot" the water, upon returning, will run red or very dirty for about five or ten seconds. Usually, when water clears up, it is proof that our job is done.

Several check valves are distributed about the blow tank, this tank being A. S. M. E. tested for 3,300 pounds.

For a plumber to attempt to obtain the results we do with an instrument has proven a failure. Releasing air in "Jackrabbit jabs" is also a failure. It is that terrific impact that does the work.

When a service is partially obstructed by a soft deposit, one "shot" will restore the original efficiency.

Our results are so satisfactory, I doubt we will ever install an X-ray machine to satisfy those who may wonder what takes place inside the service during blowing, or what it looks like after the "blow."

The 5x8 inch record card here reproduced reveals the story of a typical blowing operation. On the reverse side is the record of time required for the 2 gallon can filling from the consumer's kitchen faucet "Before and After" administering the "medicine."

ADDRESS 403 Wilson DATE 11-18 194-

WATER SERVICE – LINE INFORMATION

(1) PRESSURE ON MAIN (35#)
Length of Service (49')
Make of Service (Lead)
Age of Service (years) (45)
Size of Service (¾")

(2) BUILDING
Blown for {Dirty Water ( )
Poor Pressure (✓)
Size of Meter (¾)
Size of Building ( )
Size of Pipe Throughout ( )

(3) 1. CONDITIONS BEFORE BLOWING
Vol. Del. from ¼" Hose (¾)
Vol. Del. from ¼" Hose with Nozzle (20')

2. CONDITIONS AFTER BLOWING
Vol. Del. from ¼" Hose with Nozzle (46')

(4) COND. AFTER BLOWING FROM METER OPENING TO MAIN
Vol. Del. from Hose After:
1st Blow (9") (#60) + Pressure
2nd Blow (11¾") ( ) + Pressure
3rd Blow ( ) ( ) + Pressure
4th Blow ( )
5th Blow ( )
6th Blow ( )
Length of Hose: Long ☐ Med. ☒ Short ☐

(5) RESULTS
Color ( )
Vol. ( )

(6) FROM CURB COCK TO MAIN
No. Times ( )
Results ( )

(7) HOUSE SERVICE CONDITIONS
(a) Vol. ( )
(b) Cause {Corrosion ( )
Pipe Too Small ( )

FINAL RESULTS
( )
By ( )

Record Card

On the rear of this 5x8-in. card appears thtis information:
Time Required at Kitchen Faucet to Fll 2-Gallon Can

Before Blowing (2 min., 5 sec.)

After Blowing (20 sec.)

FLOW OF WATER IN HOUSE SERVICE PIPES

(To find the discharge in gallons, multiply by 7.48)

Condition of Discharge	Pressure in Main Pounds per Square Inch	Discharge in Cubic Feet per Minute from the Pipe								
		Nominal Diameters of Iron or Lead Service Pipe in Inches								
		½	⅝	¾	1	1½	2	3	4	6
Through 35 ft. of service pipe; no back-pressure.	30	1.10	1.92	3.01	6.13	16.58	33.34	88.16	173.85	444.63
	40	1.27	2.22	3.48	7.08	19.14	38.50	101.80	200.75	513.42
	50	1.42	2.48	3.89	7.92	21.40	43.04	113.82	224.44	574.02
	60	1.56	2.71	4.26	8.67	23.44	47.15	124.68	245.87	628.81
	75	1.74	3.03	4.77	9.70	26.21	52.71	139.39	274.89	702.03
	100	2.01	3.50	5.50	11.20	30.27	60.87	160.96	317.41	811.79
	130	2.29	3.99	6.28	12.77	34.51	69.40	183.52	361.91	925.58
Through 100 ft. of service pipe; no back-pressure.	30	0.66	1.16	1.84	3.78	10.40	21.30	58.19	118.13	317.23
	40	0.77	1.34	2.12	4.36	12.01	24.59	67.19	136.41	366.30
	50	0.86	1.50	2.37	4.88	13.43	27.50	75.13	152.51	409.54
	60	0.94	1.65	2.60	5.34	14.71	30.12	82.30	167.06	448.63
	75	1.05	1.84	2.91	5.97	16.45	33.68	92.01	186.78	501.58
	100	1.22	2.13	3.36	6.90	18.99	38.89	106.24	215 68	579.18
	130	1.39	2.42	3.83	7.86	21.66	44.34	121.14	245.91	660.36
Through 100 ft. of service pipe and 15-ft. vertical rise.	30	0.55	0.96	1.52	3.11	8.57	17.55	47.90	97.17	260.56
	40	0.66	1.15	1.81	3.72	10.24	20.95	57.20	116.01	311.09
	50	0.75	1.31	2.06	4.24	11.67	23.87	65.18	132.20	354.49
	60	0.83	1.45	2.29	4.70	12.94	26.48	72.28	146.61	393.13
	75	0.94	1.64	2.59	5.32	14.64	29.96	81.79	165.90	444.85
	100	1.10	1.92	3.02	6.21	17.10	35.00	95.55	193.82	519.72
	130	1.26	2.20	3.48	7.14	19.66	40.23	109.82	222.75	597.31
Through 100 ft. of service pipe and 30-ft. vertical rise.	30	0.44	0.77	1.22	2.50	6.80	14.11	38.63	78.54	211.54
	40	0.55	0.97	1.53	3.15	8.68	17.79	48.68	98.98	266.59
	50	0.65	1.14	1.79	3.69	10.16	20.82	56.98	115.87	312.08
	60	0.73	1.28	2.02	4.15	11.45	23.47	64.22	130.59	351.73
	75	0.84	1.47	2.32	4.77	13.15	26.95	73.76	149.99	403.98
	100	1.00	1.74	2.75	5.65	15.58	31.93	87.38	177.67	478.55
	130	1.15	2.02	3.19	6.55	18.07	37.02	101.33	206.04	554.96

From the Handbook of the Buffalo Tank Corp.

STREAMLINE PIPE AND FITTINGS DIVISION MUELLER BRASS CO.

Port Huron, Michigan

STREAMLINE Copper Pipe and STREAMLINE Solder Fittings for Water Service Work

In 1924 the Mueller Brass Co. originated and were the first to introduce a product then known as Mueller Copper Service Pipe and Flared Fittings. This was a distinct innovation and was conceded to be the most revolutionary contribution of the time for water service purposes.

Waterworks' engineers and superintendents prefer as soft copper pipe as possible for water service work. STREAMLINE Type K Pipe is consistently and uniformly soft. It is made from Virgin Copper Ingot consisting of at least 99.94% copper and throughout every phase of its manufacture is under rigid and constant laboratory control. From the time we started to manufacture this product in 1924, and throughout the years since, we have produced the best and softest pipe that can be made for water service work.

RUST-PROOF

STREAMLINE Copper Pipe is rust-proof and is superior to any other metal for service pipe work. Under normal conditions of soil and water, it will last for generations, and will deliver its full capacity of water free from foreign particles as clear and pure as it is in the water main.

FLEXIBLE

STREAMLINE Copper Service Pipe is exceptionally and uniformly flexible. It can be very quickly and easily bent around comparatively sharp radii without annealing or loading. It may easily be bent around obstructions encountered in the trench with a great deal less cost than would be entailed in removing the obstruction.

REASONABLE COST

Copper Pipe connected with STREAMLINE Fittings is very reasonable in cost, although naturally a little more expensive than rustable pipe. It really costs a great deal less over a period of time, because replacements are eliminated owing to the rust and clog-proof properties of STREAMLINE Type K Copper Pipe.

COUPLING
Copper to Copper

VIBRATION PROOF

STREAMLINE Copper Pipe connected with STREAMLINE Solder Fittings is free from the harmful effects of vibration. Vibration is not localized at the joints as it is with threaded or flared fittings, but is harmlessly dissipated throughout the service line.

PERMANENT

STREAMLINE Copper Service Pipe is permanent. Once installed it may practically be forgotten; it will give no future trouble. For years it will continue to give the same uninterrupted service and undiminished flow of water.

COUPLING
Copper to Iron

SETTLEMENT AND FROST ACTION

STREAMLINE Copper Service Pipe is so ductile that it will stretch enough to easily take care of any settlement of filled earth, or, in fact, anything that might impose a strain on the service line which would cause failure of rigid ferrous pipe or, at the very least, cause leakage at the threaded connections.

TEE

In the Northern States and in the Dominion of Canada, copper service pipe of our manufacture has an outstanding advantage that places it far in advance of any other service material. This advantage is its resistance to frost action. This service pipe containing water under almost any range of pressure used in water service work can be alternately frozen and thawed out for a considerable number of times without showing any effect except a slight increase in diameter.

STREAMLINE SOLDER FITTINGS

The STREAMLINE Solder Fitting is connected to the pipe by feeding solder through a feed hole in the fitting. Capillarity causes the solder to thoroughly bond the pipe to the fitting and produces an enormously strong joint. This joint is so strong that if, for instance, two ¾" sections of pipe are connected with a ¾" coupling and pulled in the Olsen Testing Machine, it requires approximately 9000 pounds per square inch before a failure occurs, and this failure is always in the pipe itself, and not in the joint. This is, of course, far beyond anything it would be required to stand under actual service.

COUPLING
Copper to Inside Thread

A copy of our catalog, fully illustrating and describing these products, together with simple instructions for connecting, will be sent upon request.

STREAMLINE Fittings are manufactured under Patents 1,770,852, 1,776,502, 1,890,998.

WATER METER TESTING PRINCIPLE AND PRACTICE

[*From "Testing Water Meters—Why and How"*]*

The testing of a water meter is very simple. It consists of checking the registration of the meter against the actual volume of water passing through the meter, as measured in an accurate volumetric tank or weighed on accurate scales.

Meter accuracy may be defined as the quotient obtained by dividing the meter reading by the actual volume of water. Thus a meter registering 9 gallons when 10 gallons are run through it has an accuracy of 9/10 or 90%. A meter registering 52 cubic feet on an actual volume of 50 cubic feet is 52/50, or 104% accurate.

Meter accuracy is commonly expressed in percentage fast or slow. Thus a meter which records 95 gallons when 100 gallons are run through it under-registers or is slow by 5%. A meter registering 102 gallons on the same volume would be 2% fast.

Good Practice in Testing

Before starting a test, water should be run through the meter or meters at a high rate, say 10 or 15 gallons per minute, until all the air is out of the meters and the line, and the delivery pipe to the tank is as full or as empty as it will be at the end of the test. Start the test flow with the test hand of the meter or meters on an even starting position or line on the dial. This can be done either by running water from the outlet of each meter until it has the test hand at the proper position, or the register can be turned around in the case until the test hand stands on the line.

When testing one meter at a time with calibrated tank or with scales having percentage beams, the test flow should be stopped when the meter has indicated the passage of the test amount. The percentage fast or slow of the meter can then be read direct from the tank gauge or from the percentage beam of the scales.

When testing several meters in series or when using scales or tanks without percentage markings, the flow should be stopped when the test volume of water has been run into the tank. The percentage fast or slow of the meter or meters can then be computed by dividing the meter readings by the actual amount of water. It will be seen that the computation will be much simplified if the amount of water is one, ten or one hundred gallons or cubic feet. Thus the divisor is one, which makes the meter reading direct in percentage of accuracy. Example: 100 gallons run through the meter; meter reading 96 gallons; meter accuracy 96%, or the meter is 4% slow.

Amount of Water for Tests

All test amounts except on lowest flow or "sensitive" tests should be at least enough to correspond to one complete revolution of the test hand on the meter dial. Often the test hand pinion is not in the center of the circle on the dial and this would introduce an error in reading with partial turns of the test hand. Common practice is to test on the small flows with an amount representing one revolution and on large flows with an amount representing ten revolutions of the test hand. On the other hand, it is possible to get an accurate test on a ⅝ inch meter with ten gallons or one cubic foot and many meter shops do not go beyond this. Of course the greater the amount of water the smaller would be the errors introduced by inaccuracies in readings.

Single or Series Testing

Meters can be tested one at a time or in series. When there are many meters to test there is a worth-while saving in water and time if several meters are tested at once. The number of meters in series or the number of units in the testing machine justified for any condition depend on the number of meters in the system and the frequency of testing. Testing machines or benches for up to 12 meters are in common use.

In series testing the flow can be stopped when the correct amount of water has been run through the meters into the tank, and the accuracy of each meter computed as indicated above. When only a few meters are tested in series it is possible to take advantage of the percentage calibration on the tank or scales by turning off the water when the fastest meter shows a registration of the test amount, reading the percentage accuracy of the meter, starting the flow again and stopping for each meter as it comes up to the desired reading. This method of obtaining the meter accuracy is not considered good practice as it involves changing the rate of flow for every start and stop involved.

Testing with Test Meters

For testing in the field the so-called test meter is convenient and satisfactory if only a rough check is desired. However, a test meter is only a meter and subject to the same variation in accuracy which is characteristic of all disc meters.

Further, a test meter is not positive in the same way as a tank or scales. Testing one meter with a test meter or with any other meter is simply comparing meters and is not recognized in many states which have regulations or laws applying to means or equipment for water meter testing. Field testing can be done much better and more accurately by means of a calibrated testing tank.

Money Value of Meter Accuracy

The accuracy of a water meter is a matter of dollars and cents to the customer and the utility.

Fortunately for the customers, water meters which were originally accurate cannot over-register beyond a slight speeding up in some water conditions. This action is self-limiting, for friction increases with the building up of the disc or piston and tends to counteract the speeding up. Water meters always slow down in service as they become worn, corroded or encrusted.

The intervals at which it is profitable to the water works to test meters and repair them depends entirely on the effects of the water and service conditions in making the meters under-register, on the value of the water taken but not registered, and on the cost of making the necessary tests and repairs. In other words, if the increased revenue from the meter pays a good return on the cost of making the meter accurate, it is simply *good business.*

Several states have recently adopted regulations which specify limits between meter tests in water utilities, both in time and

*A booklet distributed by Ford Meter Box Co., Wabash, Ind.

MFGR. NO. CO. NO. MAKE SIZE

DATE PURCHASED STYLE

INSTALLATION RECORD								TEST AND REPAIR RECORD								
INSTALLED		NAME	ADDRESS	Tap No.	Reasons for Removal	Removed		Date	Rate of Test			Repairs		Total Amt. of Water Passed Before Test	Tested By	REMARKS
Date	Reading					Date	Reading		Min. Flow	Inter. Flow	Max. Flow	Before Test	After Test			

Heading for a Suggested Form for Meter Record Card. This Can Be Adapted to Meet the Requirements of Any Meter Shop. Actual Size of Card Is 8½ by 11 inches.

in volume of water. These limits are necessarily broad, as the composition of water and its effect on meters varies widely in any state, and many utilities profitably test and repair more frequently than required. These regulations show the growing realization that meter testing *is* important.

The following table shows the value of water unregistered by meters of various percentages of slowness, with various amounts of water drawn through the meter and with water valued at from 10c to 50c per thousand gallons. These figures can be easily transposed into cubic ft. by recalling that 100 cubic ft. equals 750 gallons.

From the table it will be seen that with water at 10c per thousand gallons the return on the investment of testing and repairing a meter 4% slow will be only 40c with every 100,000 gallons of water drawn through the meter. It would take a large and active service to make frequent testing pay under these conditions.

On the other hand, with water at 50c per thousand gallons a meter failing to register 20% of the water passing through it (not terribly rare) would lose $1.00 for the water works with every 10,000 gallons. With these conditions maintained accuracy will pay a handsome return on the investment.

TABLE SHOWING VALUE OF WATER NOT REGISTERED BY METERS OF VARYING PERCENTAGES OF UNDER-REGISTRATION, WITH WATER FROM 10c TO 50c PER THOUSAND GALLONS, AND WITH THREE AMOUNTS OF TOTAL DRAFT.

	Value of Water Per 1,000 Gallons								
	@ 10c			@ 30c			@ 50c		
	Total Volume Drawn—Gallons x 1,000								
%*	10M	50M	100M	10M	50M	100M	10M	50M	100M
4	$ .04	$ .20	$ .40	$ .12	$ .60	$1.20	$ .20	$1.00	$2.00
6	.06	.30	.60	.18	.90	1.80	.30	1.50	3.00
8	.08	.40	.80	.24	1.20	2.40	.40	2.00	4.00
10	.10	.50	1.00	.30	1.50	3.00	.50	2.50	5.00
12	.12	.60	1.20	.36	1.80	3.60	.60	3.00	6.00
14	.14	.70	1.40	.42	2.10	4.20	.70	3.50	7.00
16	.16	.80	1.60	.48	2.40	4.80	.80	4.00	8.00
18	.18	.90	1.80	.54	2.70	5.40	.90	4.50	9.00
20	.20	1.00	2.00	.60	3.00	6.00	1.00	5.00	10.00

*Under-Registration Percent.

Steps in Testing a Water Meter

[A ⅝inch meter is used as an example. A larger meter would involve the same procedure but would require greater rates of flow.]

1. **Insert Meter in Tester**—Any means of connecting the meter water-tight in the test line is satisfactory but a regular tester is much more convenient.

2. **Flush Meter Out With a Large Flow**—This is to remove air from the meter and line. A flow of ten or more gallons per minute is desirable and should be continued until discharge indicates that all air is out of the line.

3. **Bring Test Hand of Meter to a Mark**—This can be done by stopping the water flow as the hand reaches the mark, or by turning the dial in the meter case if the meter bonnet is removed.

4. **Run a Test at 10 to 15 G.P.M. Running 50 Gallons or 10 Cu. Ft.**—It is desirable to run this much water although more would be just as good or better. Be sure the calibrated tank is empty or the scales balanced before the test flow is started.

5. **Run a Test at 1 to 2 G.P.M. Running 10 Gallons or 1 Cu. Ft.**—Here again the exact amount is subject to variation and more water can be run if there is plenty of time and water.

6. **Run ¼ G.P.M. Test, Running at Least 5 Gallons or ½ Cu. Ft.**—This low-flow test is important for reasons mentioned on pages 9 and 10.

7. **Make a Record of the Tests**—Put down in permanent form the accuracy of the meter at the three rates of flow, date of test and other pertinent information. See suggested record card on the previous page.

IMPORTANCE OF TESTING DISC METERS AT THE CORRECT RATES OF FLOW

By P. S. WILSON

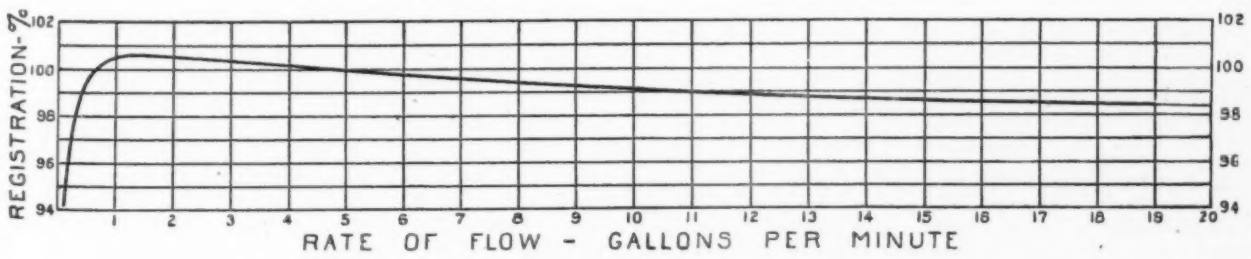
Water Works Consultant, Glen Ridge, N. J.

A TYPICAL registration curve of disc type water meters is shown. In this curve the percentage of the water actually registered during passage through the meter is plotted against the rate of flow in gallons per minute.

The curve as a whole may be shifted upwards or downwards by altering the gearing of the meters but this will not change the general shape of the curve. The curve shown in the figure is drawn for five-eighths inch meters but the corresponding curve for any size of disc meter will have much the same shape in relation to the total range of capacity of the meter. The important fact to observe regarding this curve is the fact that it is a curve and not a straight line. In other words, even above the low flows which the meter will not register, the percentage registered is not the same at different rates of flow.

Importance of Testing at Several Rates of Flow

The purpose of testing a meter is to determine the percentage of the water passing the meter which is registered by it. As explained above, this percentage is normally different at different rates of flow. In routine meter shop practice it is of course impractical to test a meter at every rate of flow under which it will actually operate, and yet we must have assurance that it will register within the limits of accuracy adopted at all of these different rates. We know that a test at a single point on the curve, that is, at a single rate of flow, will not give us the percentage registered at other rates of flow. The curve may be of different curvature depending upon the condition of the meter, and we are making the test because we do not know the condition of the meter. If the clearances in the disc chamber are too great, for example, the meter will not register the low flows well and its curve will drop off too rapidly at that end. If the "control" is not close enough, that is, if the spindle is not held at the proper angle, the meter's registration curve will in all probability go up too high at the intermediate rates of flow. With the multiplicity of parts in a meter there are of course many other defects which may have various effects upon the performance of the mechanism as a whole



Curve Showing Accuracy of Meter Registration at Variable Rates of Draught.

The endeavor must be to test the meter at the least number of rates which will serve to indicate with sufficient reliability what the performance will be over the rest of its range of capacity. It has been found that in normal practice it is necessary to make a test at each one of the three different rates of flow, unless the condition of the meter is already quite well known. In order to obtain reliable information from as few as three different rates of test, these rates must be carefully chosen in order to show up the true form of the curve and to know that there are no irregularities in it between the points located by the tests.

The three rates of flow at which a disc meter should be tested are usually termed the "Low" or "Minimum" test flow, the "Intermediate" or "Medium" test flow, and the "High" or "Full" flow.

Minimum Flow Test Requirements

The "Low" or Minimum" flow test is made in order to determine that the meter does not drop off in registration at any higher rate of flow than economically possible, in other words, the meter must be able to register down to a certain predetermined low rate with sufficient accuracy. The accuracy of registration at low flows depends to a large extent upon the reduction of clearances and at the same time the avoidance of friction in the meter.

The rates of flow called for as "Minimum Test Flow" in the Standard Specifications for Disc Type Meters as adopted by the American Water Works Association and the New England Water Works Association, and reproduced herewith as Table I, are the rates of flow in common use. Different organizations vary somewhat the required percentage of registration at these flows to suit individual views and conditions. The Standard Specifications referred to call for at least 90 per cent registration at minimum test flows. Good manufactuirng methods and skillful repair work can be considerably better than this on both new and repaired meters, 94 per cent or 96 per cent being not unreasonable to expect.

TABLE I

Rates of Test Flow. From Standard Specifications for Cold Water Meters, Disc Type, Adopted by the A. W. W. A. June 19, 1921, and by the N. E. W. W. A. Sept. 14, 1921

Size of Meter (Inches)	Normal Test Flow Limits (Gallons per Minute)	Minimum Test Flow (Gallons per Minute)
5/8	1 to 20	1/4
3/4	2 to 34	1/2
1	3 to 53	3/4
1 1/2	5 to 100	1 1/2
2	8 to 160	2
3	16 to 315	4
4	28 to 500	7
6	48 to 1000	12

Intermediate Flow Test Requirements

The Intermediate test flow should be chosen so as to ascertain that the registration at the high point of the curve does not go too high. The rates should, therefore, be such as to aim for the probable highest point. This will vary with different makes and types of meters but it will usually be found at, or a little higher than, the lower figure given under "Normal Test Flow Limits" in the Standard Specifications—see Table I. For a five-eighths inch meter the table gives 1 gal. per min. and the test flow should usually be from 1 to 2 gal. per min.

If the meter is geared and fitted so as to maintain a good registration at the low and high flows then the difficulty in most cases will be to keep the registration down at the intermediate flow. The flatter that the curve for the meter is, the less need there is for such practice. This is one of the many things to be considered in selecting a meter.

High Flow Test Requirements

The high flow test is considered by some to be the least important. This is unfortunate because it is the quickest and most convenient to perform. The exact rate of flow to be used at this test certainly is less important than with the low and intermediate tests because at rates of flow above the intermediate the curve is not apt to rise or fall so markedly. Many shops use a high test flow equal to the higher figure given under "Normal Test Flow Limits" in the standard specifications (Table I). For a five-eighths inch meter the 20 gal. per min. flow is approximately the maximum rated capacity of the meter. The practical objection to using this figure for the high test flow is that in very few cases will the service pipe and plumbing in a residence pass nearly so high a rate of flow and we are therefore testing at a rate beyond that at which the meter will ever operate. Between 50 per cent and 75 per cent of this high figure is a more logical one to use for testing in routine procedure. At the high flow the percentage registered should again be kept up, as in the low flow, and a minimum of 98 per cent is often specified in accordance with the standard specifications.

Having given consideration to the reasons for choosing each one of the three different rates of test flow it is of course self-evident that it is of equal importance to actually perform the tests at those rates, in other words, to measure with reasonable accuracy just what the rate of flow is during the test and to adjust it to the correct figure.

TABLE II

Discharge of Orifices in Gallons Per Minute. The Smaller of the Two Figures Given in Each Case Is the Discharge of a Sharp Edged Orifice in a Thin Plate. The Larger Figure Is the Discharge with Properly Rounded Edges

Size of Orifice— Inches	——Pressure—Pounds Per Square Inch—— 40	60	80	100
1/32....	0.11— 0.18	0.13— 0.22	0.16— 0.26	0.18— 0.29
1/16....	0.44— 0.74	0.54— 0.90	0.62— 1.0	0.70— 1.2
1/ 8....	1.8 — 3.0	2.2 — 3.6	2.5 — 4.2	2.8 — 4.7
3/16....	4.0 — 6.7	4.9 — 8.2	5.6 — 9.4	6.3 —10.5
1/ 4....	7.1 —11.8	8.7 —14.5	10.0 —16.7	11.2 —18.7
5/16....	11.1 —18.5	13.6 —23.	15.7 —26.	17.5 —29.
3/ 8....	16.0 —27.	19.6 —33.	23. —38.	25. —42.
7/16....	22. —36.	27. —44.	31. —51.	34. —57.
1 /2....	28. —47.	35. —58.	40. —67.	45. —75.

Importance of Accurately Measuring Flows

The most frequently used means of determining the rate of test flow is with an orifice. No fault can be found with this means if we really know how much water is flowing through the orifice.

The rate of flow through an orifice of a given size depends principally upon the shape of the edges of the hole, the thickness of the plate in which the hole is drilled, and upon the effective pressure acting to push the water through the hole. Rather than to state the size of the orifice it is far more definite to give the rate of flow in gallons per minute, or as the number of seconds to pass one cubic foot, as is done in up to the minute shops.

Table II gives the uncertainties of using orifices which have not been actually tested under fixed and known pressure. For example, a one-sixteenth inch orifice under a pressure of eighty pounds per square inch may discharge as much as one gallon per minute if the inner corners of the hole are properly rounded. On the other hand, if the edges of the hole are sharp and square and the plate through which the hole is drilled is thin the discharge may be less than two-thirds of a gallon per minute under the same pressure. Variations in the effective pressure added to the above uncertainties will of course cause even greater indefiniteness in the discharge. At forty pounds per square inch the discharge of the one-sixteenth inch sharp edged orifice may be considerably less than one-half gallon per minute, while an increase of the pressure to one hundred pounds per square inch will produce a discharge through the same orifice with round edges of over two and one-half times as much. Such uncertainties as these will greatly nullify the benefits of otherwise careful testing.

The best way to determine that the correct rate of flow is being used is to actually use a watch, and preferably a stop watch, to time the filling of a calibrated can or tank. The test flows should be stated in terms of definite figures, such as gallons per minute, and not in terms of the size of the orifice or the number of turns of the valve wheel.

The figures given in Table II are the theoretical figures as to the discharge in gallons per minute of different sizes of orifices under different pressures. The smaller of the two figures given in each case is the discharge with a sharp edged orifice in a thin plate, or with the edges properly bevelled on the outlet side. The larger figure is the maximum discharge to be expected with properly rounded edges on the inlet side of the orifice. These figures may serve as a guide in the choice by trial sizes of orifices to be used for obtaining certain rates of discharge. Actual measurement and timing should be employed to check each one, however. It must be remembered that the pressure which is effective upon the orifice will only be shown correctly by a gage located next to the orifice, and beyond the meter being tested, also that the pressure reading must be taken after the flow has become steady and constant.

SELECTING THE RIGHT METER

By ROGER W. ESTY

Superintendent, Water Works and Sewerage, Danvers, Mass.

In days gone by, the thought of "What shall we set for a meter on a service line?" was not given the consideration warranted. The expense involved apparently did not appear to be a factor, because the size of the pipe installed was generally used as the determining factor in selecting the size of meter for the installation.

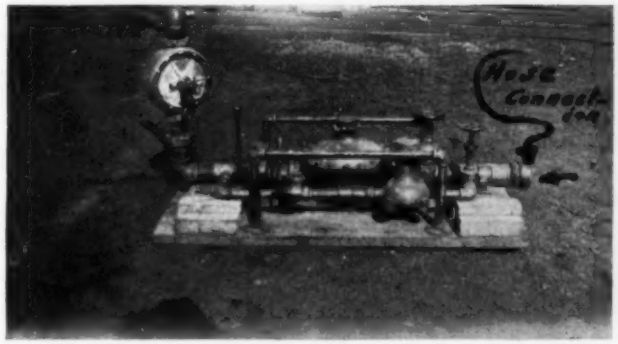
Since those days meters have reached a much higher degree of perfection and now, at reasonable cost, meters can be purchased to fit any service required; and, can be depended upon to give satisfactory results.

Especial care should be exercised when purchasing a meter because this device serves as the cash-register of the system. When purchasing a meter do not let the price be the determining factor; for, as you know, the older we get the more and more do we realize that you get just about what you pay for. There is no such thing, nowadays, as truth in a claim that "It is just as good for one-half the price."

We must not forget the obligation we owe to those we serve. We must not spend their money recklessly or unwisely.

Several years ago, at Danvers, we had a water waste survey made to check up on our consumption, which apparently was gradually creeping upward without any particular reason. Much to our surprise, we found no unreasonable leakage, but found that all of our large meters were under-registering, some as much as 50 or 60 per cent. On large meters this constitutes a sizeable and serious loss.

In the past, we never tested these meters. And, as long as they kept running and the monthly readings were comparative little, if any, attention was given them. When we found a stopped one we would take it apart and clean it and make whatever repairs found necessary. We didn't know whether the meter recorded accurately or not. We merely assumed that if it was properly cleaned and repaired it must be right.



Portable Meter Testing and Flow Measuring Outfit Used in Field Tests

After our water waste survey we changed practically every meter. Some we had rebuilt. As time went on we found that this change had been very unsatisfactory. We were suspicious of the accuracy of the readings of one large meter, realizing that its registrations must be too low. To obtain a test on it, we put in two one-inch corporation checks, brought them together, and then from this junction extended a fire hose to a two-inch test disc-meter which had been previously checked for accuracy. From this set-up approximately 200 g.p.m. was obtainable. Apparently our suspicions had been right because we found the meter under-registering. As a result of that test, we started tapping in just beyond all of the other large meters for additional testing.

Meter By-Pass Lines Proved Their Worth

From the results of this work, we decided to take out all of our institution and industrial meters, replacing them with new meters. In each case we provided a by-pass line, a test tee and the necessary gates, so that tests and repairs could be made at any time without inconvenience to the customer.

In my opinion the money spent constituted the best investment we have ever made for convenient and money saving maintenance. It is a highly justifiable expense and no meter of any consequence should be set without being provided with a properly gated by-pass with a test plug inserted.

We made mistakes in our first set-up that I would correct if I had to do the work over again. In making changes my first correction would be to set the meter on the by-pass, line and leave the main line unobstructed, to take care of large emergency demands such as would be needed at a fire. As a general rule, a meter much smaller than the size of the supply pipe can be, and should be used and there is also a saving to be had in the cost of the smaller fittings required. This is now the practice followed in Danvers.

Then, next, all gates should be provided with rising stem valves. There is a possibility of leaving gates opened or closed where the standard (non-indicating) gate stem is used. Visualization is a great safeguard and protection and at a glance one can tell the position of a rising stem valve.

Oversize Meters—Why?

After this new set-up of meters had been in for a few years, we made a 3 or 4 day test on each meter, running the recording testing device twenty-four hours each day. The results were surprising—even astounding. Meter line requirements on 6 and 8-inch pipe lines, provided with meters of the same size as the pipe, showed that at no time did the demand exceed on the 6-inch meter 25 g.p.m. and on the 8-inch meter 75 g.p.m.

From these results it was apparent that: In the first case a ¼-inch meter would amply take care of the normal demands on the 6-inch service; and in the second instance a 1¼-inch

Neptune Recording Meter Set, Used in Evalulating Variations in Water Takings by a Customer and Determining the Proper Capacity of Meter

meter would suffice on the 8-inch service. But, these meters were on lines supplying hydrants, and therefore the smaller meters could not be used. It is my opinion, however, that a 4-inch meter—if not a 3-inch meter—will prove ample. A 3-inch meter on a by-pass will supply two powerful fire streams and in most cases this will be sufficient. If a greater demand should be required the main line can be opened. Since we have a man who answers every fire alarm, he has been instructed in every instance to open up the gate on the unmetered side, regardless of how small the first might be.

We have had these smaller meters in now for nine years and we have only opened up the unmetered side of the line once. At this fire only one stream was used, but the gate was opened just the same. No difference was noticed in the volume in this instance, where a 3-inch meter had been cut into a 6-inch line leading from an 18-inch main.

What Size Service Line?

When laying a service main I thoroughly believe in laying one that will more than take care of the service demanded. Larger lines reduce friction and deliver volume up to the point of the demand. The owner should be interviewed regarding what he feels will be his maximum demand in gallons per minute. On commercial lines, I try to have the customer visualize a barrel and then tell him that that barrel holds 50 gallons. Then I ask, how much more or less than 50 gallons per minute will he use? He can readily make a comparison in his mind between the 50 gallons and the amount he is going to use and he can then easily judge about how much he will use, and it is seldom you will find any user using more than "a barrel a minute." Cubic feet means nothing to the customer, and even gallons per minute means little, but the barrel method of determining the amount of water he might use, is much easier for him to understand and has not failed yet in giving to me the information that I have wanted in determining the size of meter and service needed.

The type of service and demand, should be instrumental in determining the type of meter that should be used. Consideration of the small flows should be given prior consideration because 90 per cent of the flows come under the range of the smallest capacities of the large meters. If a large continuous flow is used, then naturally a meter to register large flows should be used as there are no small streams to be considered.

I have a case in my own system, at Danvers, where all of the water is repumped and this pump operates at about 500 g.p.m. until the tank is full, then it automatically shuts off and no more water passes through the meter until the level of the tank drops sufficient to kick in the automatic pump switch. In this case a meter to pick up minor flows, leakage, etc., is not needed, because the rate of flow is 500 g.p.m. or nothing.

The selection of the meter, should in my opinion, be left with the water works officials and *not* to the customer. The ownership of the meter should also be retained by the water department and *not* by the customer. By experience, water works managers are much better qualified than anyone else to select the proper meter which, in justice to all, must be the most adaptable to the desired type of service it is selected for.

[For the correct size of service line for a given demand a useful chart appears in Part III of the 1942 issue.—Ed.]

Renovating Water Meters

Water Companies, on the whole, and also several of the more progressive municipally owned Water Departments, have found that a little dressing up of overhauled meters before returning them to the customers' service has a desirable psychological effect on the customer. The spray gun and gilt or silver lacquer or a combination of the two is the most universally employed method of dressing up old meters after they have been overhauled and tagged "O.K." on the test bench.

Mr. La Verne Trentlage, Superintendent of Meters in the Water Department of Elgin, Ill., has evolved a scheme which goes the spray-gilting method one better in making "new" meters out of old ones. In the Elgin scheme the metal parts of the meter are given a treatment which removes the oxidized or carbonated coating from the metal and leaves the parts as metal-bright as when turned out by the manufacturer.

Cleaning and Brightening Procedure

(1) Dip meter parts for 10 minutes in *hot* Trisodium Phosphate solution (2½ lbs. or more of T.S.P. in 10 gallons of water).

(2) Remove meter parts from T.S.P. solution and rinse in *hot* water to remove the alkali.

(3) Dip the parts in Muriatic Acid solution (1 part 18 degree Muriatic Acid—to 2 parts of water). Allow to remain in this acid bath for approximately 15 minutes, or longer if necessary. Remove and rinse in hot water.

(4) To brighten to original lustre, immerse in the "bright-dip" solution (1 part 38 degree Nitric Acid, 1 part 66 degree Sulphuric Acid and 1 part water, plus a handful of common salt). Leave the parts in the bright dip for 5 to 10 seconds, the length of time depending on the composition of the metal and degree of brightness desired.

(5) Remove and rinse in *boiling* water to remove acid.

(6) To keep the parts from dulling on standing, a "stabilizing-dip" (especially prepared for this purpose) has been developed by General Chemical Company). After the rinse, the parts are dipped into this solution, removed and allowed to drain and dry.

Notes of Caution: Always add acids to water and *not* water to acids when making dilutions. This will preclude over-heating and spattering of the acid. Be careful to avoid splashing of the acid when dipping the meter parts. In case acid accidentally splashes on hands or face, wash at once in clean water to avoid an acid burn. Spattered acid is also hard on clothing and shoes. Rubber aprons and gloves are good protection.

Do not use iron or steel wire for dipping meter parts. Copper or monel metal wire is satisfactory.

CHARACTERISTICS OF NATURAL WATERS

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THE various characteristics which water manifests are due to its dissolved substances, hence a knowledge of them is of great importance to man. Besides these non-living substances all natural waters also contain living bodies, both vegetable and animal, and practically all of those changes in the character of water which produce spoilage are due to their activities.

In the following paragraphs an attempt will be made to briefly outline the outstanding effects upon water which are due to the principal constituents of the dissolved mineral load. Because water spoilage and the growths which give rise to it are of such vital importance to the water works operator special consideration will be given to the biological significance of several of these constituents.

Magnesium and Calcium Salts

Magnesium and calcium salts may be taken up first and discussed together, for they possess much in common. Both are abundant in the earth's crust, and both are readily soluble in water that contains carbon dioxide, which practically all water does. These elements are generally present in the form of bicarbonates, but sometimes they are combined as sulphates, and in some ground waters small amounts are present as chlorides, probably as a consequence of base exchange action exerted by soils.

In whatever form they may be present, salts of calcium and magnesium impart to water the property known as "hardness." Hard waters are undesirable for domestic use, and also for some industrial applications, because the calcium and magnesium react with the fatty acids of soaps to produce insoluble calcium and magnesium soaps which have no cleaning value and which float in the water as curdy flakes. So much soap is consumed in this way before a lather can be produced that hard waters are expensive to use. In addition there is the annoyance caused by the difficulty of washing the curdy material out of fabrics.

When hard waters are used for steam making they deposit their load of lime and magnesia upon the boiler tubes in the form of hard or soft scale. This coating not only wastes large amounts of fuel but causes the tubes to burn out through overheating. To improve hard waters for domestic and industrial use they must be softened, a proceeding which will be referred to again in a later paragraph.

For agricultural purposes calcium and magnesium are welcome constituents, and every irrigator hopes the water he uses may contain them in greater quantities than it does sodium and potassium, for salts of these latter bases cause "alkali" damage to soils and crops, while salts of the first two not only cause no such trouble, but may be made to rehabilitate a soil which has already been damaged by alkali.

Sodium and Potassium

Sodium and potassium are present in all waters. However, the potassium is so small in amount that it may generally be ignored and sodium regarded as the only alkali. In fresh waters, except those which are properly described as "alkali" waters, sodium is less in amount than calcium, the order of abundance being calcium, magnesium and sodium, while in sea water the order is exactly reversed, sodium being dominant and magnesium holding second place. In waters other than those intended for irrigation and some industrial uses sodium salts cause no trouble unless they are present in sufficient quantity to be perceptible to the taste, cause foaming in boilers or interfere with industrial processes, including laundrying.
esses, including laundering.

The acid radicles with which the bases are in equilibrium demand careful attention, for in some respects they seem more troublesome and more active than the bases. Six of them will be discussed here. viz., carbonate, bicarbonate, chloride, sulphate, nitrate and phosphate.

Carbonate, Bicarbonate and Carbon Dioxide

The carbonate radicle consists of one atom of carbon united to three atoms of oxygen, and is represented by the chemical symbol CO_3. It owes its characteristics to the carbon atom, as will be readily seen when we realize that if for the atom of carbon we substitute an atom of sulphur we have the sulphite (SO_3) radicle. Carbon makes carbonates just as sulphur makes sulphites and sulphates and nitrogen makes nitrates, represented respectively by the symbols CO_3, SO_3, SO_4, and NO_3. In some ways this carbon in carbonates is the most important element dissolved in water, especially in its effect upon the biology of water, but also as it affects certain aspects of water treatment. It occurs in water in three forms, viz., free carbon dioxide (CO_2), in the carbonate radicle (CO_3) and in the bicarbonate radicle (HCO_3).

Carbon dioxide (CO_2) is a colorless and almost tasteless gas which occurs as a by-product of metabolism, and is given off by all living things. It is produced in great quantities in lakes and streams wherever organic matter is being broken down under bacterial attack. Irrigation water percolating through the soil of cultivated fields carries this gas in solution to the subterranean reservoir to be pumped back to the surface from our wells. There are also deep sources of carbon dioxide from decomposing organic deposits laid down ages ago.

When it is dissolved in water carbon dioxide behaves in every way as though it had taken up the elements of water to form carbonic acid ($CO_2 + H_2O = H_2CO_3$), but carbonic acid has never been isolated in its natural state, and is known only in its compounds. Acting as an acid it combines with bases to form two classes of salts, viz., normal (or mono-) carbonates, such as calcium carbonate ($CaCO_3$), and bicarbonates (known as acid carbonates, since they retain one or two unreplaced hydrogen atoms), of which calcium bicarbonate $Ca(HCO_3)_2$ is typical. The bicarbonates of calcium and magnesium are readily soluble in water, while the corresponding normal carbonates are only sparingly soluble as such, but, and this is very important in water works practice, in the presence of free carbon dioxide (carbonic acid) these carbonates take up a molecule of carbonic acid and are converted into bicarbonates, so their solubility is a conditional characteristic dependent upon the environment.

Carbon is to be described as a "labile" element, for it moves readily from combination to combination, and in the living organism as well as in its by-products it migrates so regularly and easily that we speak of the "carbon cycle." Particularly in stored waters, but also to a lesser degree in ground waters, carbon is constantly moving around its cycle as it plays its role in the drama of life. To realize more fully the importance of this we have but to remember, that the manufacture of all food for the use of all living things, including man, starts with the linking of carbon dioxide and water which are built up into sugars and starches through the energy of sunlight acting upon chlorophyll in the cells of a green plant. All plants in water, including the plankton algae, are engaged in this task of manufacturing the primary food supply of the entire aquatic population. They first utilize the dissolved free carbon dioxide, but when this is exhausted they are able to indirectly release and use the half-bound carbon dioxide in bicarbonates, which are consequently changed to normal carbonates and removed from solution. In some instances this process has been observed to go so far in lakes as to result in a reduction of the total hardness by as great an amount as ten parts per million. It is interesting to note that if we could thus remove all the free carbon dioxide and convert all the bicarbonates to normal carbonates and maintain this condition (an impossibility) we would have no plankton algae to cause color, odor and taste in our water, for they would all starve to death for lack of available carbon. In this process of breaking down the bicarbonates to carbonates the pH value of waters have been known to be increased to 10.5 which is verging on causticity. At this point most of the algae die rapidly.

The carbonate radicle constantly comes into play in waters, and is a great aid in water treatment. To destroy growths of algae it is convenient to apply copper sulphate to water in reservoirs, using an amount seldom in excess of one part per million. When this is done the copper salt at first dissolves, but very quickly it reacts with the carbonate radicle to form a carbonate of copper which is insoluble and which settles out completely in a few hours, leaving the water copper free. The same reaction is helpful where copper pipes are used to carry water, for the carbonate radicle makes unlikely the occurrence of copper poisoning as it prevents copper from remaining in solution. If there

were no carbonates present this metal would remain in solution indefinitely and poisoning might result.

Chlorides

Chloride in potable waters is usually a minor constituent, although sometimes it may amount to 100 or 200 parts per million, at which concentrations it may be troublesome in waters which are put to certain industrial uses. The threshold value at which this radicle becomes perceptible to the taste is usually stated to be 250 parts per million.

Sulphates

The sulphate radicle (SO_4), when present in high concentration, especially if in equilibrium with sodium (forming Glauber's salt) or magnesium (Epsom salt) is likely to give water a laxative reaction. When it is in combination with calcium or magnesium it confers that property known as "permanent" or "non-carbonate" hardness, a condition which affects the choice of methods for softening treatment.

The essential element in the sulphate radicle is sulphur, which exhibits a "cycle" comparable to that of carbon. It is one of the elements which is indispensable to life and for this reason it is of great importance in the biology of water. It is quite as labile as carbon. Under the action of living organisms it passes readily from the elemental form to sulphuric acid, to sulphide and sulphate, and quite as readily reverses its path at any point in the cycle, hence it is not surprising to find it playing unexpected tricks to embarrass the unwary plant operator. When water containing considerable organic matter and sulphates (the amount of the latter radicle does not greatly affect the condition) is held in closed pipes so long that the dissolved oxygen becomes exhausted, then certain types of bacteria, which seem never to be missing, will attack sulphates for the purpose of liberating oxygen to satisfy their metabolic need, and sulphide is produced as a by-product, causing spoilage. If hydrogen sulphide is present it is likely to foster growths of an organism called Beggiatoa, which is unable to flourish except in the presence of this gas, and Beggiatoa in turn reduces the hydrogen sulphide to elementary sulphur, which may next be oxidized to sulphuric acid by other common bacteria. This acid then reacts with carbonates to form sulphates with the release of free carbon dioxide, and so these cycles roll onward, wheels within wheels, which turning reciprocally give rise to alternate life and death in the cycle of living organisms. Hydrogen sulphide in dead ends of distribution systems is indicated by "black-water" and vile odor when mains are flushed.

The Cycles Go On

One of the fundamental laws of science which water works operators must ever remember teaches that matter can never be destroyed; we can so greatly change its form that it may be unrecognizable to our senses, or we may tear its atoms asunder and dissipate them as smoke and ashes, but that matter still exists and it will later return in some new form which may be even more noisome. When we have once gotten rid of some objectionable substance, or compound, or organism, we must remain on guard lest, rising from its ashes, like the Phenix of old, it may haunt us anew, for the cycles which make life possible as well as the cycle which is life itself can be slowed down, but they cannot be permanently stopped. Successive plankton pulses follow each other throughout the year, each deriving part or all of its food from the degradation products of its predecessor.

Nitrates and Phosphates

Nitrates (NO_3) and phosphates (PO_4), are usually found in but small amount in unpolluted waters, but their biological importance is great, for both are essential plant foods, readily available to promote excessive development of plankton algae, or, worse still as far as odors and tastes are concerned, they support troublesome growths of bacteria. The nitrogen "cycle" is quite as vital to life as that of carbon or sulphur. The subtle causes which underlie the appearance of plankton "pulses" in lakes and reservoirs are believed to center in the limiting values of these two radicles, and in Europe considerable research has been directed toward the elucidation of this problem.

Iron and Manganese

Iron and manganese, two closely related metals, are sometimes found in troublesome quantity in surface waters, especially those contaminated by mine drainage or industrial wastes. More commonly either or both may be present in material amount in ground water, where they cause much trouble if water is to be used for domestic or industrial purposes. Water containing these metals is usually clear and sparkling as it comes from the ground, but after exposure to the air the metals become oxidized which renders them insoluble and they then cause the water to appear opalescent and later dirty owing to the separation of the oxides in flecks and masses. Such waters cause stains on clothes washed in them and upon plumbing fixtures. They also promote troublesome growths of an organism known as Crenothrix which may grow so abundantly in pipes as to greatly reduce their carrying capacity. Iron and manganese waters are common in Southern California and Crenothrix growths have been encountered in many of our large supplies. Both of these metals should be removed from water before it is admitted to pipe systems. Due to corrosive attack upon the pipes iron often causes trouble in a distribution system carrying water which at its source was iron free.

Borates and Fluorides

Boron is a metal which is found in small quantities in some waters but which is of little importance except when water is used for irrigation. When present in quantities exceeding 0.75 part per million, measured as elementary boron, it is likely to injure lemons and some other crops.

Fluorine is another troublesome element in waters in some localities. When present in water used by children, before the advent of their permanent teeth, this radicle causes an unsightly affliction of the teeth known as mottled enamel. The threshold value above which enamel damage is expected to appear is placed at 1.0 part per million of fluorine in the form of fluorides.

Treatment

The treatment accorded water to enhance its value for human use varies from simple settling to remove suspended matter to elaborate dosage with several different chemicals, aided by mechanical mixing, followed by retention to permit chemical reactions to reach completion, filtration to remove the products of reaction and final adjustment to stabilize the character of the finished water. Aeration is employed to remove odor, carbon dioxide, hydrogen sulphide, as well as iron and sometimes manganese. Coagulation with such chemicals as aluminum sulphate, sodium aluminate, ferric chloride, ferrous sulphate, etc., is employed to remove suspended matter which is so fine that it will not settle out, and filtration is used to remove the "floc" formed by the coagulant and with it most of the bacteria. Sterilization (the word is commonly employed, but it should be understood that it is a misnomer, as the resting stages of bacteria and other organisms are not destroyed) with chlorine, or sometimes by ozone or ultra-violet rays, is used to remove all trace of disease-producing organisms which might be present in the raw water. Activated carbon, in powdered and in granular form, is employed to remove objectionable odors and tastes.

Softening is generally accomplished by the addition of quick lime or hydrated lime to remove the carbonate hardness, and of sodium carbonate (soda ash) to remove the non-carbonate hardness. The soda-lime process obviously cannot reduce hardness below the solubility of calcium carbonate and magnesium hydroxide, a value which is in the neighborhood of 60 parts per million expressed as calcium carbonate ($CaCO_3$), depending on the pH.

Softening can also be effected by filtering water through beds of zeolite, which is a complex hydrated aluminum silicate that contains sodium loosely linked into its molecule. Calcium and magnesium in the hard water replace the sodium in the silicate and in this way water of zero hardness can be readily produced.

After a certain volume of water has been softened the zeolite becomes saturated with calcium and magnesium and can do no further work until it has been regenerated. This is accomplished by treating the zeolite with a strong solution of salt (sodium chloride) during which the sodium displaces the calcium and magnesium which are washed out into the brine. Zeolite softening has no effect upon the acid radicles as ordinarily practiced, but there is now available an exchange material which will effect the removal of carbonates and other acid radicals.

For a presentation of treatment plant operation and control, the writer wishes to urge all students of the subject to secure a copy of one small book which he considers the very best brief treatise of water purification, and one which is expressed in simple and direct language. It will answer most of your questions. The book is "Water Supply and Treatment," written by Charles P. Hoover, the leading exponent of water softening in America. It is published by the National Lime Association, Washington, D. C., as Bulletin No. 211, for distribution at 50 cents per copy.

INTERPRETATION OF CHEMICAL ANALYSES OF WATER

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WATER works men are continually being confronted with results of chemical analyses of waters and not infrequently are puzzled as to what the figures mean. It is hoped that the following will be helpful in interpreting and understanding such analyses.

Expression of Results

In the United States, the results of chemical analyses of water are expressed usually either as parts per million or as grains per gallon. One part per million is equivalent to one unit of weight of the substance being reported in one million units of water; as, for instance, one pound of the substance in one million pounds of water. Since one gallon of water weighs approximately 8.3 pounds, one part per million is equivalent to 8.3 pounds of substance in one million gallons of water. One grain per gallon means that each gallon of water contains one grain or 1/7000 of a pound of the substance being reported. One grain per gallon is equivalent to 17.1 parts per million or 143 pounds per million gallons.

TABLE 1

	Equivalents		
Unit	Grains per U. S. gallon	Parts per million	Pounds per million gallons
1 grain per U. S. gallon..	1.0	17.1	143
1 part per million.....	0.058	1.0	8.3

At one time analytical results were expressed quite generally in grains per gallon. The American Public Health Association, in its publication, "Standard Methods for the Examination of Water and Sewage," however, recommends that results be expressed in parts per million and the recent trend has been in that direction. In the treatment of water the dosages of chemicals employed are expressed in grains per gallon added, although modern trend is toward the use of lbs./m.g. for all chemicals involved.

Analytical results may also be expressed in terms which are readily understood chemically. The chemical formula or the name of the compound in terms of which each substance or radical is reported, should be given. For instance, if magnesium is reported as: magnesium hardness = 50 parts per million, it is difficult to determine immediately just how much magnesium the water contains. If, however, magnesium is reported as: magnesium hardness (expressed as $CaCO_3$) = 50 p.p.m., it is at once apparent that magnesium is present in an amount molecularly equivalent to 50 p.p.m. of calcium carbonate ($CaCO_3$). Only those results which are properly and completely reported can be properly interpreted.

Judging the Sanitary Quality of Water from Chemical Results

Before about 1890, it was customary to attempt to judge the sanitary quality of water from chemical analyses. Since the development of bacteriological methods, however, chemical analyses have been little used for this purpose except as a check or for comparative purposes. The substances determined and their significance from a sanitary standpoint will now be discussed briefly.

Four different forms of nitrogen are determined for a sanitary chemical water analysis. It is known that the nitrogen present in fecal matter is in the form of protein and that, starting from that form, the nitrogen goes through a cycle of changes whereby it is converted first from the protein or albuminoid ammonia form to so-called free ammonia (mineral ammonia), then to nitrite and finally to nitrate. The total amount of nitrogen, properly valued, indicates the extent of fecal pollution, and the relative amounts of the four forms of nitrogen indicate the extent to which oxidation has proceeded. Nitrates, however, may come from mineral deposits and alone have no sanitary significance.

The amount of oxidizable organic matter in water is indicated properly valued, the latter also indicates the presence of organic pollution, but is a better indicator of industrial waste pollution than of sewage pollution.

Chloride is present in many waters, usually as sodium chloride, and in itself is harmless. Since, however, sewage contains a relatively large amount of chloride, any unusual increase in the chloride content of a water may be evidence of pollution.

Turbidity indicates the presence of suspended matter and may be either organic or inorganic. In order to meet U. S. Treasury Department Standards for Drinking Water, turbidity must not exceed 10 (silica scale) and in general it should not exceed 5.

As a measure of the sanitary quality of water, the above chemical analyses are of most value when used for comparative purposes. If these analyses are made as a matter of routine and the normal content of each for the water in question is well known, an increase above the normal might well be considered to indicate sewage pollution. Of greatest value are these tests in conjunction with well waters.

Alkalinity:

Alkalinity in water is determined by titrating a sample with N/50 acid using two indicators, phenolphthalein and methyl orange and is reported in terms of calcium carbonate. Bicarbonates, normal carbonates, and hydroxides, are the three types of compound which produce alkalinity in water and by using both phenolphthalein and methyl orange indicators, it is possible to determine how much of each type of alkalinity is present.

Methyl orange measures all of the alkalinity, bicarbonates, normal carbonates, and hydroxides. Phenolphthalein measures none of the bicarbonates, but does half of the normal carbonates, and all of the hydroxides. If phenolphthalein indicator is added to a solution containing only bicarbonate alkalinity, the solution will remain colorless. If added to a solution containing only normal carbonates the solution will turn red and, when titrated with standard acid, the end point to phenolphthalein will be exactly half way to the end point to methyl orange. This is because each milli-liter (ml.) of titrating acid releases an equivalent amount of carbonic acid which affects phenolphthalein the same as the titrating acid. If phenolphthalein is added to a solution containing only hydroxides, the solution will turn red and the end point to phenolphthalein will be exactly the same as the end point to methyl orange. If some of both normal carbonate and hydroxide are present the phenolphthalein end point will be somewhere between the two extremes cited.

Most natural waters contain bicarbonates only and normal carbonates and hydroxides are usually produced by lime treatment. The phenolphthalein-methyl orange titration makes it possible to determine quickly and accurately whether the proper amount of lime is being added to the water in softening or in corrosivity reduction with lime or other alkali.

When lime is added to a water containing calcium bicarbonate the following reaction takes place:

$$CaH_2(CO_3) + Ca(OH)_2 \longrightarrow 2CaCO_3 + 2H_2O$$

(calcium bicarbonate) (lime) (calcium carbonate) (water)

The reaction takes place as shown in the equation when exactly the right amount of lime is added to the water to convert all of the calcium bicarbonate to calcium carbonate and, when titrated, the end point to phenolphthalein will be exactly half the end point to methyl orange because the alkalinity will be due to the small amount of calcium normal carbonate remaining in solution. If lime is added in insufficient quantity to react with all of the calcium bicarbonate, the water will contain both calcium bicarbonate and calcium normal carbonate and, when titrated, the end point to phenolphthalein will be less than one-half the end point to methyl orange. If lime is added in excess of the amount required to react with all of the calcium bicarbonate, the water will contain calcium normal carbonate and free lime or calcium hydroxide and, when titrated, the end point to phenolphthalein will be more than one-half the end point to methyl orange.

From the foregoing explanation, the following rules can be derived (Ph. = alkalinity to phenol. MO. = alkalinity to methyl orange; both expressed in parts per million):

1. If 2 Ph. is less than M.O., then 2 Ph. = normal carbonates
2. If 2 Ph. is more than M.O., then 2 Ph. — M.O. = hydroxides and M.O. — hydroxides = normal carbonates.
3. If 2 Ph. = M.O., then all alkalinity is due to normal carbonates.

If the alkalinity is less than the total hardness, then the alkalinity is due to carbonate hardness. If the alkalinity is more than the total hardness, then the total hardness is all carbonate hardness and the excess alkalinity (alkalinity — total hardness) is sodium alkalinity.

Hardness:

Hardness in water is due principally to compounds of calcium and magnesium which are in solution and to a lesser (usually inconsequential) extent, to compounds of iron and aluminum.

Hardness, like alkalinity, is expressed in terms of calcium carbonate. Hardness is determined in a number of ways, the most important being, by calculation, by the soap method and by the soda reagent method. (See "Standard Methods of Water Analysis"—A.P.H.A. and A.W.W.A.)

The most accurate method for determining the total hardness of a water is to compute the calcium carbonate equivalent of the calcium, magnesium and, if present in sufficient quantity, iron and aluminum content. Usually the iron and aluminum can be neglected. If a water analysis shows the calcium and magnesium content, the total hardness can be computed as follows:

$$Ca \times 2.495 + Mg \times 4.115 = \text{hardness as } CaCO_3$$

The soap method is the most rapid means of determining hardness but is also the least accurate, especially when the determination is made by an inexperienced person. Hardness as determined by the soap method should always be considered as approximate and, if accuracy is necessary, some other method should be employed. This is especially true of the determination of calcium hardness from the false end point or ghost point in the soap hardness determination.

Either total hardness or non-carbonate hardness can be determined by the soda reagent method. Due to the fact that calcium carbonate and magnesium hydroxide are slightly soluble, this method is not strictly accurate but is sufficiently so for routine control work. The soda reagent method is commonly used in controlling the operation of lime-soda ash water softening plants.

When results of hardness determinations of water are being studied and interpreted, it is always well to know the method of analysis used. Then the proper weight can be given to the results reported.

Dissolved Gases

Free carbon dioxide and dissolved oxygen are often determined in making complete water analyses. The accuracy of the results reported for these two gases depends to a great extent upon the accuracy with which the samples are collected. It is always well to bear in mind that while the analyses may be accurate, the sample may have been collected in such a way as to allow the escape or absorption of considerable amounts of gas.

When results are reported in terms of positive and negative radicals the figures are usually unsatisfactory to the layman because they give but a hazy idea of the composition of the water. The results are more readily understood if hypothetical combinations are calculated or if the results are expressed graphically

Computing Most Probable Compounds

In computing hypothetical combinations, the method of Hale (Jour. Am. Chem. Soc., 29, 1078; 1907) is usually used. In this method, the positive and negative radicals are combined with each other in the following order:

Calcium	Bicarbonate
Magnesium	Sulphate
Sodium	Chloride
Potassium	Nitrate

Calcium is first combined with bicarbonate. If there is excess calcium above that required for bicarbonate, it is combined with sulphate, chloride, and nitrate, until exhausted. If there is excess bicarbonate above that required for calcium, it is combined with magnesium, sodium, and potassium, until exhausted. As each positive and negative radical is used up, the next following radical is combined until the radicals on both sides are exhausted. If the analysis has been made correctly, the positive and negative radicals will be present in equivalent amounts.

The first step in calculating hypothetical combinations is to determine the reacting values of each of the positive and negative radicals in the water in accordance with the following formula, in which (R) is the radical in question:

$$\text{Reacting value} = (R) \text{ in p.p.m.} \times \frac{\text{valence of (R)}}{\text{mol. wgt of (R)}}$$

The term $\frac{\text{valence of (R)}}{\text{mol. wgt. of (R)}}$ is called the "reaction coefficient," and for various positive and negative radicals has values as follows:

REACTION COEFFICIENTS

Positive radicals	Negative radicals
Calcium (Ca) 0.0499	Carbonate (CO_3) 0.0333
Magnesium (Mg) 0.0822	Bicarbonate (HCO_3) 0.0164
Sodium (Na) 0.0435	Sulphate (SO_4) 0.0208
Potassium (K) 0.256	Chloride (Cl) 0.0282
Hydrogen (H) 0.992	Nitrate (NO_3) 0.0161

The following is a typical water analysis giving the various positive and negative radicals in parts per million and the calculated reacting values:

Analysis			Reacting Value	Analysis			Reacting Value
Ca	81 ×	.0499 =	4.04	HCO_3	177 ×	.0164 =	2.90
Mg	25 ×	.0822 =	2.05	SO_4	180 ×	.0208 =	3.74
Na	30 ×	.0435 =	1.31	Cl	27 ×	.0282 =	.76
			7.40				7.40

The reacting values give a measure of the relative amounts of the positive and negative radicals present in the water. The 81 p.p.m. of calcium, with a reacting value of 4.04, is present in sufficient amount to combine with all of the bicarbonate and with 4.04 — 2.90 = 1.14 of the reacting value of the sulphate—second in the order of negative radicals to combine with calcium. Magnesium, with a reacting value of 2.05, is not present in sufficient amount to use up all of the sulphate remaining and 3.74 — (1.14 + 2.05) = .55 of the reacting value of the sulphate remains to combine with the sodium. The reacting values will be distributed and evaluated as follows:

Ca as calcium bicarbonate	2.90
Ca as calcium sulphate	1.14
Mg as magnesium sulphate	2.05
Na as sodium sulphate	.55
Na as sodium chloride	.76
Total	7.40

Determining Actual PPM. of Each Compound

In order to determine the actual amount of each hypothetical combination present in parts per million, it is necessary to multiply the reacting value by a combination factor. The combination factor is the factor necessary to convert the radical reported into the compound sought divided by the reaction coefficient. For instance, the factor for converting Ca to $CaCO_3$ is 2.5 and the reaction coefficient for Ca is .0499. The combination factor for converting the reacting value for Ca to $CaCO_3$ will therefore be 2.5 ÷ .0499 = 50. The following is a table of combination factors:

Given the Reacting Values	Sought	Combination Factor
For Ca or CO_3	$CaCO_3$	50.0
For Ca or SO_4	$CaSO_4$	68.1
For Ca or Cl	$CaCl_2$	55.5
For Ca or NO_3	$Ca(NO_3)_2$	82.0
For Mg or CO_3	$MgCO_3$	42.2
For Mg or SO_4	$MgSO_4$	60.2
For Mg or Cl	$MgCl_2$	47.6
For Mg or NO_3	$Mg(NO_3)_2$	74.2
For Na or CO_3	Na_2CO_3	53.0
For Na or SO_4	Na_2SO_4	71.0
For Na or Cl	NaCl	58.5
For Na or NO_3	$NaNO_3$	85.0

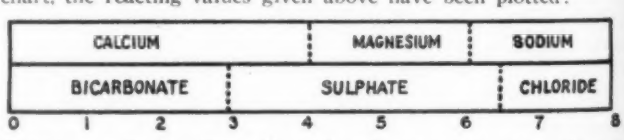
Applying the combination factors to the above analysis, the following hypothetical combinations are obtained:

Calcium bicarbonate ($CaCO_3$)	2.90 × 50.0 =	145 p.p.m.*
Calcium sulphate ($CaSO_4$)	1.14 × 68.1 =	78 p.p.m.
Magnesium sulphate ($MgSO_4$)	2.05 × 60.2 =	123 p.p.m.
Sodium sulphate (Na_2SO_4)	.55 × 71.0 =	39 p.p.m.
Sodium chloride (NaCl)	.76 × 58.5 =	44 p.p.m.

*Bicarbonate $Ca(HCO_3)_2$ in terms of $CaCO_3$

Graphical Plotting to Picture Combinations

Reacting values may also be plotted graphically to show the relative amounts of each radical present. If the reacting values for Ca, Mg, and Na are laid off to scale in that order on one line, and the reacting values for HCO_3, SO_4, and Cl are laid off to scale in that order on another line directly under the first, the relative amounts of each are at once apparent. On the chart, the reacting values given above have been plotted:



Graph, to Scale, Revealing Overlapping Combinations of Radicals and Clearly Revealing a Picture of Chemical Make-up of Waters.

When properly interpreted, results of chemical analyses of water are very valuable in determining the quality of the water, and the treatment necessary to improve the quality.

PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS*

Standards Adopted by the United States Public Health Service, Federal Security Agency, September 25, 1942, for Drinking and Culinary Water Supplied by Common Carriers in Interstate Commerce

(Superseding Standards adopted June 20, 1925)[1]

IN RECOMMENDING the adoption of the revised Standards the Advisory Committee submitted a report discussing the requirements as follows:

Report of the Advisory Committee on Official Water Standards

The "Treasury Department Drinking Water Standards," were last revised in 1925, and published in the Public Health Reports of April 10 of that year. Since that time many improvements in water supply practice have been adopted with resulting increased uniformity of quality and safety to the consumer. Moreover, the Public Health Service, in recent years, has been requested by the American Public Health Association, the American Water Works Association, and the American Chemical Society to review the 1925 Standards. Accordingly, the Public Health Service has undertaken a revision of the Standards in order to have them conform more closely to current requirements for water supplies of attainable safety and potability.

To carry out such a revision the Surgeon General of the Public Health Service appointed a special Advisory Committee composed of representatives of various Federal organizations and scientific associations and including several members at large.

After thorough consideration, the advisory committee recommends the adoption of the revisions as set forth in the text herewith submitted. The principal changes proposed follow:

(1) A distinct separation of the text into: (a) that portion containing the statement of the Standards, and (b) that portion constituting a recommended manual of water practice representing the judgment of the technical sub-committee composed of officers of the Public Health Service. This portion of the text is intended to serve as a guide to the reporting agency and should not be considered as indicating additional requirements to be met for certification of the water supply.

(2) In the bacteriological section the use of 5-10 ml. portions or of 5-100 ml. portions is made optional; a minimum number of samples is to be examined monthly, the number depending upon the population served; the laboratories in which bacteriological examinations are made and the methods used in making them are subject to inspection at any time by the designated representative of the certifying authority.

(3) Concentration limits for lead, fluoride, arsenic, and selenium are included as part of the Standards and their presence in excess of the limits stated shall constitute ground for rejection of the supply. Limits in concentration that should not be exceeded, where other more suitable supplies are available, are given for copper, iron and manganese together, magnesium, zinc, chloride, sulfate, phenolic compounds, total solids, and alkalinity.

(4) The results of recent studies on the potential pollutional hazards existing in the water supply systems of our communities due to faulty plumbing practices, cross-connections, interconnections, etc., as well as the pollutional hazards which are due to faulty water plant and distribution system operational practices, any or all of which may jeopardize the safety of the water in the distribution system, have been adjudged as being of prime importance in the consideration of the requirements of these Standards. The utmost care and consideration have been given to the inclusion of those provisions which would serve to detect possible contamination arising in the distribution system and thus lead to its correction and further safeguarding of the traveling public.

The Committee believes that, in general, water supplies to be eligible for certification should meet all (sanitary, chemical, and bacteriological) requirements of the Standards and that definite failure to meet any one of them should be ground for rejection or provisional certification, according to the judgment of the certifying authority. However, it is realized that the statement of an official standard of drinking water quality, to be generally applicable, must be interpreted reasonably. The Committee has attempted to take into consideration all aspects of the problem. It offers these Standards with the recommendation that the judgment and discretion of the certifying authority be exercised in their application.

Part I—Public Health Service Standards

1. Definition of Terms

FOR the purpose of these Standards the terms designated herein below shall be defined as follows:

1.1. *Adequate protection by natural agencies* implies various relative degrees of protection against the effects of pollution in surface waters; dilution, storage, sedimentation, the effects of sunlight and aeration, and the associated physical and biological processes which tend to produce natural purification; and, in the case of ground waters, storage in and percolation through the water bearing material.

1.2. *Artificial treatment* includes the various processes commonly used in water treatment, both separately and in combination, such as storage, aeration, sedimentation, coagulation, rapid or slow sand filtration, chlorination, and other accepted forms of disinfection. Rapid sand filtration treatment is commonly understood to include those auxiliary measures, notably coagulation and sedimentation, which are essential to its proper operation.

1.3. *Adequate protection by artificial treatment* implies that the method and degree of elaboration of treatment are appropriate to the source of supply; that the works are of adequate capacity to support maximum demands, are well located, designed, and constructed, are carefully and skillfully operated and supervised by properly trained and qualified personnel, and are adequately protected against floods and other sources of pollution. The evidence that the protection thus afforded is adequate must be furnished by frequent bacteriological examinations and other appropriate analyses showing that the purified water is of good and reasonably uniform quality, a recognized principal being that irregularity in quality is an indication of potential danger. A minimum specification of good quality would be conformance to the bacteriological and chemical requirements of these Standards, as indicated in sections 3 and 4.

1.4. *Sanitary defect* means any faulty structural condition, whether of location, design or construction of water collection, treatment or distribution works, which may regularly or occasionally cause the water supply to be contaminated from an extraneous source, including dual supplies, by-passes, cross-connections, or interconnections (backflow connections) or fail to be satisfactorily purified.

1.5. *Health hazard* means any faculty operating condition including any device or water treatment practice, which, when introduced into the water supply system, creates or may create a danger to the well-being of the consumer.

1.6. *Water supply system* includes the works and auxiliaries for collection, treatment, and distribution of the water from the source of supply to the free-flowing outlet of the ultimate consumer.

1.7. *The coliform group of bacteria* is defined, for the purpose of these Standards, as including all organisms considered in the coli-aerogenes group as set forth in the Standard Methods for the Examination of Water and Sewage, eighth edition (1936), prepared, approved and published jointly by the American Public Health Association and the American Water Works Association, New York City. The procedures† for the demonstration of bacteria of this group shall be those specified herein, for:

(*a*) The completed test, or

(*b*) The confirmed test when the liquid confirmatory medium brilliant green bile lactose broth, 2 percent, is used, providing the formation of gas in any amount in this medium during 48 hours of incubation at 37° C. is considered to constitute a positive confirmed test, or

(*c*) The confirmed test when one of the following liquid confirmatory media is used: crystal violet lactose broth, fuchsin lactose broth, or formate ricinoleate broth. For the purpose of this test, all are equivalent, but it is recommended that the laboratory worker base his selection of any one of these confirmatory media

*From *Public Health Reports* (Vol. 58, No. 3; Reprint 2440), January 15, 1943.

†This reference shall apply to all details of technique in the bacteriological examination, including the selection and preparation of apparatus and media the collection and handling of samples, and the intervals and conditions of storage allowable between collection and examination of the water sample.

upon correlation of the confirmed results thus obtained with a series of completed tests, and that he select for use the liquid confirmatory medium yielding results most nearly agreeing with the results of the completed test. The incubation period for the selected liquid confirmatory medium shall be 48 hours at 37° C. and the formation of gas in any amount during this time shall be considered to constitute a positive confirmed test.

1.8. *The standard portion of water* for the application of the bacteriological test may be either:

(*a*) Ten milliliters (10 ml.) or

(*b*) One hundred milliliters (100 ml.).

1.9. *The standard sample* for the bacteriological test shall consist of five (5) standard portions of either:

(*a*) Ten milliliters (10 ml.) or

(*b*) One hundred milliliters (100 ml.) each.

In any disinfected supply the sample must be freed of any disinfecting agent within twenty (20) minutes of the time of its collection.†

1.10 *The certifying authority* is the Surgeon General of the United States Public Health Service or his duly authorized and designated representatives and the *reporting agency* shall be understood to mean the respective State departments of health or their designated representatives.

2. As to Source and Protection

2.1. The water supply shall be:

(*a*) Obtained from a source free from pollution; or

(*b*) Obtained from a source adequately purified by natural agencies; or

(*c*) Adequately protected by artificial treatment.

2.2 The water supply system in all its parts shall be free from sanitary defects and health hazards and shall be maintained at all times in a proper sanitary condition.

3. As to Bacteriological Quality

3.1. *Sampling.*—The bacteriological examination of water considered under this section shall be samples collected at representative points throughout the distribution system.

The frequency of sampling and the location of sampling points on the distribution system should be such as to determine properly the bacteriological quality of the water supply. The frequency of sampling and the distribution of sampling points shall be regulated by the certifying authority after investigation of the source, method of treatment, and protection of the water concerned.

†In freezing samples of chlorine or chloramines, the procedure given on page 286 in the Standard Methods for the Examination of Water and Sewage, eighth edition (1936), paragraph A-1—option 1, or paragraph A-2 shall be follwed.

The minimum number of samples to be collected from the distribution system and examined by the reporting agency or its designated representative each month should be in accordance with the number as determined from the graph presented in figure 1 of these Standards ‡ which is based upon the relationship of population served and minimum number of samples per month:

Population served	*Minimum number of samples per month*
2,500 and under	1
10,000	7
25,000	25
100,000	100
1,000,000	300
2,000,000	390
5,000,000	500

The laboratories in which these examinations are made and the methods used in making them shall be subject to inspection at any time by the designated representative of the certifying authority. Compliance with the specified procedures, or failure to comply therewith, and the results obtained shall be used as a basis for certification, or refusal of certification, by the certifying authority in accordance with the application given below.

3.2. *Application.*—Applications 3.21 and 3.22 given below shall govern when ten milliliter (10 ml.) portions are used and applications 3.23 and 3.24 shall govern when one hundred milliliter (100 ml.) portions are used.§

3.21. Of all the standard ten milliter (10 ml.) portions examined per month in accordance with the specified procedure, not more than ten (10) percent shall show the presence of organisms of the coliform group.

3.22. Occasionally three (3) or more of the five (5) equal ten milliliter (10 ml.) portions constituting a single standard sample may show the presence of organisms of the coliform group, provided that this shall not be allowable if it occurs in consecutive samples or in more than

‡For the purpose of uniformity and simplicity in application, the number of samples to be examined each month for any given population served shall be determined from the graph in accordance with the following:

For populations of 25,000 and under to the nearest 1.
For populations of 25,001 to 100,000 to the nearest 5.
For populations of 100,001 to 2,000,000 to the nearest 10.
For populations of over 2,000,000 to the nearest 25.

§It is to be understood that in the examination of any water supply the series of samples for any one month must conform to both of the above requirements, either 3.21 and 3.22 or 3.23 and 3.24, respectively.

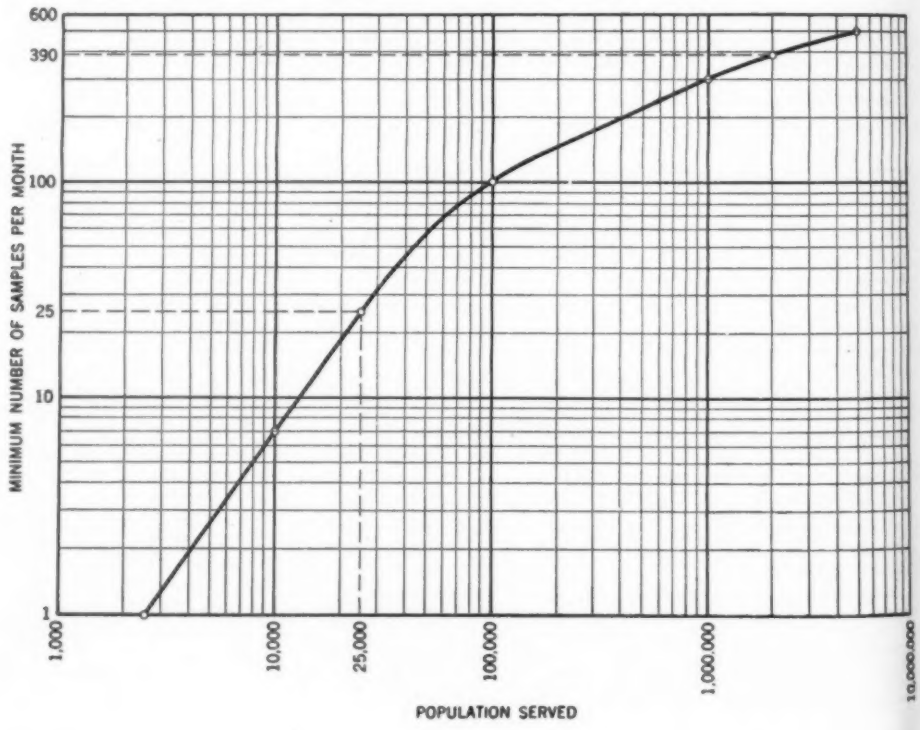


Figure 1 — Relation Between Minimum Number of Samples to be Collected per Month and Population served.

(*a*) Five (5) percent of the standard samples when twenty (20) or more samples have been examined per month.

(*b*) One (1) standard sample when less than twenty (20) samples have been examined per month.

Provided further that when three or more of the five equal ten milliliter (10 ml.) portions constituting a single standard sample show the presence of organisms of the coliform group, daily samples from the same sampling point shall be collected promptly and examined until the results obtained from at least two consecutive samples show the water to be of satisfactory quality.#

3.23. Of all the standard one hundred milliliter (100 ml.) portions examined per month in accordance with the specified procedure, not more than sixty (60) percent shall show the presence of organisms of the coliform group.

3.24. Occasionally all of the five (5) equal one hundred milliliter (100 ml.) portions constituting a single standard sample may show the presence of organisms of the coliform group, provided that this shall not be allowable if it occurs in consecutive samples or in more than

(*a*) Twenty (20) percent of the standard samples when five (5) or more samples have been examined per month.

(*b*) One (1) standard sample when less than five (5) samples have been examined per month.

Provided further that when all five of the standard one hundred milliliter (100 ml.) portions constituting a single standard sample show the presence of organisms of the coliform group, daily samples from the same sampling point shall be collected promptly and examined until the results obtained from at least two consecutive samples show the water to be of satisfactory quality.**

3.25. The procedure given, using a standard sample composed of five standard portions, provides for an estimation of the most probable number of coliform bacteria present in the sample as set forth in the following tabulation:

Number of portions		Most probable number of coliform bacteria per 100 ml.	
Negative	Positive	When 5-10 ml. portions are examined	When 5-100 ml. portions are examined
5	0	Less than 2.2	Less than 0.22
4	1	2.2	.22
3	2	5.1	.51
2	3	9.2	.92
1	4	16.0	1.60
0	5	More than 16.0	More than 1..60

4. As to the Physical and Chemical Characteristics

4.1. *Physical characteristics.*—The turbidity of the water shall not exceed 10 p.p.m. (silica scale), nor shall the color exceed 20 (standard cobalt scale). The water shall have no objectionable taste or odor.

4.2. *Chemical characteristics.*—The water shall not contain an excessive amount of soluble mineral substance, nor excessive amounts of any chemicals employed in treatment. Under ordinary circumstances, the analytical evidence that the water satisfies the physical and chemical standards given in section 4.1 and 4.21 and simple evidence that it is acceptable for taste and odor will be sufficient for certification with respect to physical and chemical characteristics.

4.21. The presence of lead (Pb) in excess of 0.1 p. p. m., of fluoride in excess of 1.0 p. p. m., of arsenic in excess of 0.05 p. p. m., of selenium in excess of 0.05 p. p. m., shall constitute ground for rejection of the supply.

These limits are given in parts per million by weight and a reference to the method of analysis recommended for each determination is given in section 4.31. Salts of barium, hexavalent chromium, heavy metal glucosides, or other substances with deleterious physiological effects shall not be allowed in the water supply system.

Ordinarily analysis for these substances need be made only semi-annually. If, however, there is some presumption of unfitness because of these elements periodic determination for the element in question should be made more frequently.

#When this occurs, and when waters of unknown quality are being examined, simultaneous tests should be made on multiple portions of a geometric series ranging from 10 ml. to 0.1 ml. or less.

**When this occurs, and when waters of unknown quality are being examined, simultaneous tests should be made on multiple portions of a geometric series ranging from 100 ml. to 1.0 ml. or less.

4.22. The following chemical substances which may be present in natural or treated waters should preferably not occur in excess of the following concentrations where other more suitable supplies are available in the judgment of the certifying authority. Recommended methods of analysis are given in section 4.3.

Copper (Cu) should not exceed 3.0 p. p. m.

Iron (Fe) and manganese (Mn) together should not exceed 0.3 p. p. m.

Magnesium (Mg) should not exceed 125 p. p. m.

Zinc (Zn) should not exceed 15 p. p. m.

Chloride (Cl) should not exceed 250 p. p. m.

Sulfate (SO_4) should not exceed 250 p. p. m.

Phenolic compounds should not exceed 0.001 p. p. m. in terms of phenol.

Total solids should not exceed 500 p. p. m. for a water of good chemical quality. However, if such water is not available, a total solids content of 1,000 p. p. m. may be permitted.

For waters softened by the lime soda process the total alkalinity produced should not exceed the hardness by more than 35 p. p. m. (calculated as $CaCO_3$).

For chemically treated waters the phenolphthalein alkalinity (calculated as $CaCO_3$) should not be greater than 15 p. p. m. plus 0.4 times the total alkalinity. This requirement limits the permissible pH to about 10.6 at 25° C.

For chemically treated waters the normal carbonate alkalinity should not exceed 120 p. p. m. Since the normal alkalinity is a function of the hydrogen ion concentration and the total alkalinity, this requirement may be met by keeping the total alkalinity within the limits suggested when the pH of the water is within the range given. These values apply to water at 25° C.

pH range:	*Limit for total alkalinity (p.p.m. as $CaCO_3$)*
8.0 to 9.6	400
9.7	340
9.8	300
9.9	260
10.0	230
10.1	210
10.2	190
10.3	180
10.4	170
10.5 to 10.6	160

4.3. Recommended methods of analysis:

4.31. Ions with required limits of concentration.

Arsenic (As): Official and Tentative Methods of Analysis. Association of Official Agricultural Chemists, 1940, p. 390; also "Colorimetric Microdetermination of Arsenic," Morris B. Jacobs and Jack Nagler. Industrial and Engineering Chemistry, Anal. Ed., 14:442 (1942).

Fluoride (F): Standard Methods for the Examination of Water and Sewage. American Public Health Association, 1936, p. 36; also Methods of Determining Fluorides, Committee Report, A. P. Black, Chairman. Journal American Water Works Association, 33:1965-2017 (1941).

Lead (Pb): Standard Methods for the Examination of Water and Sewage. American Public Health Association, 1936, p. 26.

Selenium (Se): Official and Tentative Methods of Analysis. Association of Official Agricultural Chemists, 1940, pp. 11 and 417; also Robinson, W. O., Dudley, H. C., Williams, K. T., and Byers, Horace G.: The Determination of Selenium and Arsenic by Distillation. Industrial and Engineering Chemistry, Anal. Ed., 6:274 (1934).

4.32. Ions and substances with suggested limits of concentration.

Copper (Cu): Standard Methods for the Examination of Water and Sewage. American Public Health Association, 1936, p. 25.

Iron (Fe) and manganese (Mn): Ibid, p. 74 and p. 82.††

Magnesium (Mg): Ibid, p. 79.††

Zinc (Zn): Ibid, p. 28.††

Chloride (Cl): Ibid, p. 34.††

Sulfate (SO_4): Ibid, p. 85.††

Phenolic compounds: Ibid. p. 245.†† With dibromquinonechlorimide as an indicator.

Total solids: Ibid, p. 56.††

Alkalinity: Ibid, pp. 59 and 64.††

††For the chemical determinations referred to in this report, when given, the methods of analysis recommended by the Association of Official Agricultural Chemists are satisfactory and may be substituted for those recommended by the American Public Health Association, which are specifically cited.

Manual of Recommended Water Sanitation Practice Accompanying United States Public Health Service Drinking Water Standards, 1942

(Prepared by Technical Subcommittee)

This manual is not to be considered as part of the Standards which must be met in order to obtain certification of the water supply, but is intended to serve as a guide to the reporting agency.

Introduction

In its report accompanying the 1942 Drinking Water Standards the Advisory Committee recommended, as the principal change to be incorporated in the revision, a separation of the text into (*a*) that portion containing the statement of the Standards, and (*b*) that portion which constitutes a recommended manual of water works practice, representing the judgment of the technical subcommittee, composed of officers of the Public Health Service, and which is to serve as a guide to the reporting agency. The Advisory Committee further stated, "This latter portion of the text is not to be considered as part of the Standards which must be met in order to obtain certification of the water supply."

In undertaking the preparation of a manual such as envisioned by the Advisory Committee, the technical subcommittee has recognized that no comprehensive treatise on water supply practice is needed in this connection, in view of the several excellent texts which have been published on this subject, including a recent manual (*2*) issued by the American Water Works Association. It considers its task, in fact, to be limited to a comparatively brief and general description of those features of water supply systems and their operation which may be said to conform to accepted principles of good sanitation. It is very largely with these features that the reporting agency is concerned in forming a judgment as to whether or not a particular water supply may meet reasonably acceptable sanitary requirements in respect to its source and protection, as prescribed in section 2 of the Standards. As a further aid to the reporting agency, a section designated as part IV, containing an explanatory discussion of the bacteriological and chemical requirements of the Standards, has been added to this manual. This section is virtually an appendix, as it deals with a subject quite distinct from that of the other sections of the manual.

The main text of the manual, other than part IV, is divided into three sections, parts I, II and III. In part I are given in outline form those features of water supply systems which may be included in the sanitary survey, including a list of major sanitary defects and health hazards which would be detrimental to the safety of a water supply. In parts II and III are two sections dealing, respectively, with recommended sanitary requirements for water treatment and for water distribution systems. These two parts of the manual are in the form of a connected discussion, amplifying the outline material given in part I.

In preparing the manual, full advantage has been taken of criticisms of the preliminary text by various members of the Advisory Committee. Although it obviously would be impossible to reconcile fully the conflicting views of any group as large as this committee, an effort has been made to follow, so far as practicable, the concensus of opinion among a majority of the committee. The writers of the manual take this opportunity to acknowledge gratefully the many helpful comments which have been furnished by members of the Advisory Committee on the material herein presented.

In preparing the present manual, cognizance has been taken of the need which exists for affording somewhat greater sanitary protection to certain features of public water supply systems and their operation under the existing wartime conditions than might be considered as essential under those of peace. In general, however, an effort has been made to write the manual from the viewpoint of normal requirements for water sanitation as they would be considered by the reporting agency in connection with the application of the Drinking Water Standards.

PART I

PHYSICAL FEATURES OF WATER SUPPLY SYSTEMS AND THEIR SANITARY PROTECTION

The physical features of water supply systems may be said to include all of those parts which come within the definition given in paragraph 1.6 of the Standards. According to this definition, "a water supply system includes the works and auxiliaries for collection, treatment, and distribution of the water from the source of supply to the free-flowing outlet of the ultimate consumer." Strictly interpreted, sanitary protection would be concerned with all of those parts of a water system which come within this definition, though for practical purposes the attention may be concentrated mainly on those parts which have to do with sources, treatment, and distribution of the water.

A. Scope of Requisite Information as to Source and Protection

In order that the administrative authorities may have the necessary information upon which to base their action, it is required that each water supply coming under consideration should be carefully studied with reference to its source and protection. The precise scope of such a study and of the report thereon will vary according to the circumstances existing in each individual case and cannot be fully specified in any general terms. The general procedure, however, should be substantially as follows:

1. *A sanitary survey of the water supply should be made by a competent person.* The reliability of the data collected will depend largely upon the competence of the person by whom the survey is made, and the careful selection of personnel for this duty is of primary importance. The qualifications which constitute "competence" cannot be precisely defined, but, in general, the person making the survey should have received a technical education in the basic sanitary sciences equivalent to that given in a course in sanitary engineering in a recognized college of engineering or school of public health; he should have a broad knowledge of the sanitary features and physical facts concerning water supplies for potable use, and he should understand the essential features of water purification plants, their operation and methods of testing.

2. *A brief general description of the water supply should be submitted.* This should include the name of the owner of the supply and a brief description of sources and catchment areas, of the storage available both prior to and following any treatment, and of the plant, with date of installation of main works, and record of subsequent extensions or alterations.

3. *A brief summary of the pertinent facts relating to the sanitary condition of the water supply, as revealed by the field survey, should be submitted.* The following outline will serve to indicate the general scope of the survey. Not all of the items, however, would be pertinent to any one supply, and in some cases items not in the list would be important. Reference should be made to parts II and III of this manual for certain detailed recommendations bearing on various parts of this outline.

(A) Small Ground Water Supplies

1. Nature of soil and underlying porous strata, whether of clay, sand, or gravel; thickness of water-bearing strata; depth to water table.
2. Nature of rock penetrated, noting especially existence of porous limestone.
3. Depth to strainers; length of strainers; depth of casing; well construction—material—diameter.
4. Slope of water table, preferably as determined from observational wells, or as indicated presumptively but not certainly by slope of ground surface.
5. Nature, distance and direction of sources of pollution.
6. Possibility of surface drainage water entering the supply, and of wells being flooded by nearby streams.
7. Methods of protection.
8. Pump house construction (floors, drains, etc.); capacity of pumps; draw-down when pumps are in operation.
9. Disinfection: equipment; supervision; laboratory control.

(B) Large Ground Water Supplies

1. General character of local geology.
2. Extent of drainage area likely to contribute water to the supply.
3. Size and topography of catchment area; slope of ground surface.
4. Nature and porosity of soil and underlying strata, whether clay, sand, gravel, rock (especially limestone); coarseness of sand or gravel; thickness of water-bearing strata.

5. Depth of strainers; length of strainer; depth of casing.
6. Population on the drainage area.
7. Nature, distance, and direction of local sources of pollution.
8. Pump house construction (floors, drains, etc.); capacity of pumps; draw-down when pumps are in operation.
9. Possibility of surface drainage water entering the supply; methods of protection.
10. Methods used for protecting the supply against pollution, by means of sewage treatment, waste disposal, and the like.
11. Protection of collecting well at top and on sides; protection other than check valve or gate against backflow of drain, etc.
12. Availability of an impure emergency supply.
13. Use of tile pipes or other conduits not tight where ground water may be contaminated.
14. Disinfection: equipment; supervision; laboratory control.

Examples of sanitary defects in ground water supplies are:

(1) Caves, sink holes, or abandoned borings used for surface drainage or sewage disposal in vicinity of the source; fissures or open faults in strata overlying water-bearing formations.
(2) Casing of tubular wells leaky, or not extended to sufficient depth, or not extended above ground or floor of pump room, or not closed at top; or casing improperly used as a suction pipe.
(3) Collecting well or reservoir subject to backflow of polluted water through improper drain.
(4) Source of supply or structures subject to flooding.
(5) Leak in systems under vacuum.
(6) Air lift or lines cross-connected to a sewer or secondary water supply.

(C) Surface Water Supplies, Unfiltered

1. Nature of surface geology; character of soil and rocks.
2. Character of vegetation, forests, cultivated land, etc.
3. Population and sewered population per square mile of catchment area.
4. Methods of sewage disposal, whether by diversion from watershed or by treatment.
5. Character and efficiency of sewage treatment works on watershed.
6. Proximity of sources of fecal pollution to intake of water supply.
7. Proximity, sources, and character of industrial wastes.
8. Adequacy of supply as to quantity.
9. For lake or reservoir supplies: wind direction and velocity data; drift of pollution; sunshine data (algae).
10. Character and quality of raw water—algae, turbidity, color, coliform (M.P.N.), (average, minimum and maximum).
11. Nominal period of detention in reservoir or storage basin.
12. Probable minimum time required for water to flow from sources of pollution to reservoir and through reservoir to intake.
13. Shape of reservoir, with reference to possible currents of water, induced by wind, from inlet to water supply intake.
14. Measures taken to prevent fishing, boating, landing of airplanes, swimming, wading, ice cutting, or permitting animals in or upon the water, etc.
15. Efficiency and constancy of policing.
16. Disinfection of water: Kind and adequacy of equipment, duplication of parts; effectiveness of treatment, adequacy of supervision and laboratory control; contact period after disinfection; whether residual free chlorine or chloramines in chlorinated water; residuals carried.

Examples of sanitary defects are:

(1) Absence or inadequacy of chlorination, or lack of proper control of chlorination; insufficient contact period with chloramines present in treated water.
(2) Insufficient restrictions on recreational use of streams and reservoirs, together with their marginal lands, in the local catchment area.
(3) Existence of sources of pollution, such as population on watershed, lumbering, hunting, and other activities; leaching cesspools, or sewers draining into streams or lakes of the catchment area, or into the marginal lands adjacent to them.
(4) Improper location of intake with respect to bottom of reservoir and current, or to surface drainage water inlets.
(5) Intake exposed and accessible to trespassers.
(6) For lake supplies: Vessels passing near intakes; drift of ice fields; dumping of dredging, garbage, etc., into lakes near intakes; inadequate toilet facilities on cribs; nonexamination of employees as carriers of water-borne diseases.

(D) Surface Water Supplies, Filtered

1. Catchment area: Size, topography; population density (sewered and unsewered); surface geology; reservoirs (capacity and location).
2. Sources of pollution: Nature; distance from intake (miles and time of travel); amounts and distances of sewered population.
3. Sewage treatment on watershed: Extent; methods; populations served; effectiveness and uniformity of results.
4. Raw water characteristics: Turbidity, color, alkalinity, hardness, iron, etc.; bacterial quality (average and ranges); variations in quality, especially after heavy rainfall or at times of high run-off.
5. Rated capacity of filter plant (mgd.): Output (average and maximum daily); maximum capacity of pumps.
6. Coagulant system: Type (solution or dry feeding); chemicals used; dosage rates (average, maximum, and minimum); number and capacity of units; reserve units.
7. Mixing and flocculation basins: Type; flash mixing (average and minimum times); flocculation (average and minimum times); number, size, and arrangement of units; provisions for cleaning.
8. Sedimentation basins (number, size, and retention capacity): Plain sedimentation; post-coagulation sedimentation; methods of cleaning; flexibility of operation; efficiency of turbidity and bacterial removal.
9. Filters: Type (pressure or gravity); number; sizes and rated capacities (net filtering area); effective size and uniformity coefficient of sand; washing system (direct or from storage, rates of wash water application); loss-of-head gages; rate controllers (average and maximum rates of filtration).
10. Filtered water storage: Capacity; location; arrangement; covered or uncovered; protection against contamination; methods of cleaning; added storage in distribution system.
11. Aeration. Kind, purpose, capacity, location in purification system; efficiency.
12. Disinfection: Kind, stages (if more than one); location in purification system; capacity; method of operation; operation control; average, maximum and minimum dosage; chlorine—ammonia ratios (if ammonia used); simple or "break-point" chlorination (if used); efficiency of each stage.
13. Plant operation and control: Technical supervision (trained or untrained, full-time or part-time); number of operators; laboratory control (kind and frequency of tests); plant and laboratory records (kind, extent, use, etc.); meteorological records.

Examples of sanitary defects are:

(1) Excessive raw water pollution in relation to extent of treatment provided (see part II, A (1)); existence of nearby uncontrolled sources of raw water pollution.
(2) By-pass connections for raw water or partially treated water, whereby insufficiently purified water may be discharged into the distribution system.
(3) Existence of cross-connections within the plant, between conduits or basins carrying untreated or partly treated water and those containing completely treated water.
(4) Deficient output capacity of treatment works, necessitating excessive overloading or occasional by-passing of units.
(5) Lack of competent supervision and operation, or of adequate laboratory control.
(6) Deficient or inaccurate operation or laboratory records.
(7) Lack of suitable devices for measuring and recording volumes of water treated; for maintaining continuity of coagulant and chlorine dosage; deficient retention periods in settling basins; or inadequate areas, depths, sizes of sand or washing facilities for filters.
(8) Lack of deficiency in proper chlorination equipment and control, or failure to maintain proper chlorine residuals in the treated effluent at all times.
(9) Lack of suitable protection for purified water; storage capacity less than requirements for safety.

(E) Pumping Station and Collecting System

1. Number, type, and capacity of pumps, including reserve; condition of equipment and method of operation; condition of suction pipes.
2. Emergency intakes.
3. Emergency supply of power; record of power shut-down; effect of shut-down on surges through conduits, etc.
4. Recording apparatus on suction well elevation; rise and fall of suction well elevation.
5. Screens for fish and debris.
6. All sewers cast iron, or otherwise.
7. Curb walls around wells to protect against surface drainage.
8. Continuous or intermittent operation.

Examples of sanitary defects are:

(1) Leaky suction pipes.
(2) Pumps not self-priming; unsafe water used for priming.
(3) Suction well or suction pipes unprotected from surface or subsurface pollution.
(4) Suction well subject to pollution through backflow of polluted water through drain.
(5) Improper location or inadequate protection with reference to flood waters.
(6) Lack of suitable provision for insuring continuity of pumping service under all possible conditions.

(F) Distribution System

1. Area and population supplied (proportion to total within corporate limits).
2. Type of distribution system; whether by gravity, direct pumping, indirect pumping, etc.
3. Use, location, and capacity of reservoirs and standpipes.
4. Adequacy of distribution system with respect to area served, sizes of mains and laterals, circulation of water, storage provided, etc.

Examples of sanitary defects are:

(1) Existence of cross-connections between primary supply and secondary supply of questionable safety at any point in the distribution system.
(2) Return to the system of any water used for cooling; hydraulic operations, etc.
(3) Absence, or inadequate protection, or improper location of distribution reservoirs, standpipes, or elevated pressure tanks.
(4) Intermittent service, resulting in reduced or negative pressures in distribution system; sizes of mains and laterals inadequate for preventing negative pressures; presence of dead ends permitting reduced or negative pressures.
(5) Connections to sprinkler systems using toxic solutions as anti-freeze.
(6) Repumping on consumer premises when pressure is low (causing negative head).
(7) Connection to sewers and sewer-flushing chambers, and improperly located blow-offs in distribution system.
(8) Lack of check valves on consumer services to prevent backflow (especially from high building storage tanks), or from ammonia systems at ice plants, or from hot water systems.
(9) Existence of hydrant wash lines connected to sewer.
(10) Presence of a secondary water system on premises where public system exists.
(11) Lack of suitable plumbing ordinances prohibiting the use of backflowing toilet or sink fixtures, or permitting the use of storage tanks connected directly to sanitary fixtures without proper vacuum breaker inlets, or permitting unsafe cross-connections between potable and nonpotable water supplies in private premises.
(12) New connections of pipe line joined to the system without prior disinfection of pipes.
(13) Existence of tile or other leaky pipes in distribution system.
(14) Improper location of water pipes in relation to sewers and storm water drains.

PART II

RECOMMENDED SANITARY REQUIREMENTS FOR WATER TREATMENT SYSTEMS

A. General Requirements

(1) Extent of Treatment

(*a*) For purposes of classification with respect to treatment requirements, waters acceptable for treatment may be divided into the following groups:

GROUP 1. *Waters requiring no treatment.*—This group would be limited to underground waters subject to no possibility of contamination and meeting in all respects the requirements of these Standards, as shown by regular and frequent sanitary inspections and laboratory tests.

GROUP 2. *Waters requiring simple chlorination, or its equivalent.*—This group would include both underground and surface waters, subject to a low degree of contamination and meeting the requirements of these Standards in all respects except as to coliform bacterial content, which should average not more than 50 per 100 ml. in any month.

GROUP 3. *Waters requiring complete rapid-sand filtration treatment, or its equivalent, together with continuous postchlorination.*—This group would include all waters requiring filtration treatment for turbidity and color removal waters of high or variable chlorine demand, and waters polluted by sewage to an extent such as to be inadmissible to groups 1 and 2, but containing numbers of coliform bacteria averaging not more than 5,000 per 100 ml. in any month and exceeding this number in not more than twenty (20) per cent of the samples examined in any month.

GROUP 4. *Waters requiring auxiliary treatment in addition to complete filtration treatment and postchlorination.*—This group would include waters meeting the requirements of group 3 with respect to limiting monthly average coliform numbers, but showing numbers exceeding 5,000 per 100 ml. in more than twenty (20) per cent of the samples examined during any month and not exceeding 20,000 per 100 ml. in more than five (5) per cent of the samples examined during any month.

Note.—By "auxiliary treatment" is meant presedimentation or prechlorination, or their equivalents, either separately or combined, as may be necessary. Long-time storage, for periods of 30 days or more, represents a permanent and reliable safeguard which in many cases would provide something more than an effective substitute for one or both of the two other methods indicated.

Remarks.—(*a*) Although group 1 conceivably might include exceptional surface waters free of any possible contamination and further protected by storage, it hardly can be considered as a safe general rule to admit any surface water to a public supply without chlorination as a minimum safeguarding treatment, in view of the present increased hazards of chance contamination resulting from the extension of recreational and migratory travel to many hitherto inaccessible places. Under wartime conditions, additional need would exist for extreme precaution in this respect.

(*b*) The limiting monthly average coliform numbers stated for waters of groups 2 and 3 are intended as guides rather than inflexible rules, though they are based on extensive observational data (3) fairly representing present water treatment practice in this country. Certain recent improvements in water chlorination and its control offer promise of increasing the margin of safety of water purification efficiency, with respect to bacterial removal. These improvements have not, however, become fully incorporated into general practice throughout the country, nor does it appear desirable that they should be regarded as warranting any relaxation in the requirements for raw water quality which experience and present standards of safety would indicate as being necessary for providing adequate protection to sources of water supply in general.

(*c*) For waters of group 4, which differ from those of group 3 only in respect to variability, auxiliary treatment is intended mainly as a factor of safety in controlling variations in coliform numbers within the range of 5,000 to 20,000 per 100 ml. The larger of these two figures represents the maximum safe limit for prechlorination, or its equivalent, in addition to filtration treatment and postchlorination.

(*d*) Waters failing to meet the requirements of groups 1, 2, 3, or 4 would be considered as unsuitable for use as a source of water supply, unless they could be brought into conformance with these requirements by means of prolonged preliminary storage, or some other measure of equal permanence and reliability.

(2) Other Raw Water Requirements

In addition to meeting the aforesaid bacterial requirements, waters acceptable for treatment should not contain any toxic or otherwise harmful substances, or organisms not readily and completely removable by ordinary water treatment. Raw waters should be free of excessive amounts of acid, microscopic organisms, or organic matters causing any interference with the normal operation and efficiency of water treatment processes.

B. Design and Construction

In general, the design and construction of individual water treatment plants will vary with local circumstances and should be in accordance with the results of experiments on the water to be treated. The following recommendations, therefore, are intended only as a general guide to good practice and are to be interpreted somewhat broadly in the light of the particular raw water characteristics and other conditions which may be involved in a given situation.

(1) Plant Delivery Capacity

The delivery capacity of a treatment plant, including filtered water storage at the plant, should always be in excess of the

maximum expected draft on any day of the year. The excess of provided capacity over average daily draft may vary from 50 to 100 per cent and normally should be at least 50 per cent.

(2) Plant Location

The treatment plant, including raw water and effluent pumps, should be located at an elevation sufficiently high above surrounding bodies of water and have sufficient auxiliary power to insure continuance of operation under all circumstances, including floods. If located in a valley, the site should be adequately drained so that no surface water can gain access to wells, basins, filter tanks or other units. The plant should be located so that no conduit, basin, or other structure containing or conducting water in the process of treatment can possibly be affected by leakage from any sewer, drain, or other source of contamination.

(3) Presettling Reservoirs

Presettling reservoirs should be located above the influence of flood waters. They should be at least two in number, so as to permit continuous operation under all circumstances, and should be of sufficient capacity to afford a nominal retention period of at least 1 day and preferably 2 or 3 days. Provision should be made for rapid and convenient removal of sludge from the reservoirs. In the treatment of highly polluted waters of variable quality, provision should be made for coagulation at the inlet and for prechlorination at the inlet or the outlet of the reservoirs, whenever such measures may be necessary. Reservoirs should be provided with boats and life preservers for the protection of employees.

(4) Coagulation-Sedimentation Basins

In order to insure continuous operation, basins for flocculation and sedimentation of coagulated waters should be at least two in number, should be designed for series or parallel operation, and preferably should provide a total retention period of at least 5 or 6 hours, except where the use of preliminary mixing and flocculating devices and continuous sludge removal permit somewhat lower periods with unimpaired efficiency. Inlets and outlets of ordinary straight-flow basins should be at opposite ends of the basins and, if necessary, should be provided with baffles so located as to prevent short circuiting. Similar baffles may be advantageously installed in the settling compartment. The maximum velocity of flow in the settling compartment should not exceed that which usually is provided in well-designed basins of this type. The length of settling compartments in such basins, if rectangular, should be preferably at least twice the width. Stilling compartments should be provided at basin inlets. If stream use will permit, sludge drains may discharge at points located well downstream from the intake, or intakes, at points removed from the influence of cross-currents passing the intake. Otherwise, suitable sludge disposal areas should be provided. The depth of basins should be such as to maintain proper velocity of flow and sludge removal, the permissible depth being slightly lower with continuous sludge removal. Flow line elevations should not vary more than a few inches above or below the normal level.

Flash mixing and flocculation tanks.—Preliminary flash mixing and flocculating equipment, capable of adequate flexibility of adjustment to provide optimum flocculation under varying raw water conditions, is a highly desirable feature of well-designed modern filtration plants and should be credited as a distinct addition to the sanitary protection afforded by a purification system. An ideal combination of flash mixing and flocculation would provide about 1 to 2 minutes of violent agitation followed by about 20 to 30 minutes of slow mixing to promote flocculation.

(5) Coagulant System

Rapid-sand filtration plants should be provided with efficient modern devices for measuring and adding coagulants to the water under treatment. All chemical dosing equipment, whether of the dry-feed or solution-feed type, should have at least one unit in reserve throughout and should be provided with effective recording and alarm devices to insure continuity of service at all times. An accurate flow meter should be provided for the water treated and also for dry-feed equipment, suitable gravimetric devices for measuring the amount of chemicals added from hour to hour. All chemical feed equipment should be capable of ready adjustment to variations in the flow of water being treated.

(6) Filters

Slow-sand.—Slow-sand filters, if properly designed and operated, are applicable to the treatment of certain types of relatively clear waters. They preferably should be covered, should be provided with loss-of-head gages, should have a sand depth of 36 to 40 inches, and should never be operated with less than 20 inches of depth. The sand should have an effective size of 0.25 to 0.35 mm. and should be operated at rates of about 2.5 million gallons per acre daily. In operating slow-sand filters, care should be taken to avoid any sudden increase in the rate of filtration.

Rapid-sand.—Rapid-sand filters should be preferably of the gravity type, in order to permit ready and continuous inspection. The depth, effective size, and uniformity of sand should be in accordance with the requirements of adequate yield and filter efficiency. Ordinarily, sand depths of about 30 inches are customary, with effective sand size ranging from 0.40 to 0.50 mm. and uniformity coefficient from 1.5 to 2.0. The rate of filtration should conform to established practice, preferably not exceeding 3 gallons per minute per square foot of filtering area.

In general, rapid-sand filters should be designed and operated with a view to maintaining reasonably high efficiency of bacterial removal, and the filtering medium should be in good condition, free of mud balls, cracks, and other hindrances to efficient filtration. Efficient loss-of-head gages, rate controllers, and other essential control devices should be provided.

(7) Filtered Water Storage Reservoirs

Filtered water reservoirs at the plant preferably should be covered and located near to, but physically separated from, the plant. Where located below filters, adequate protection against leakage of drainage water from other parts of the plant into the reservoirs should be provided. Trap doors and inspection openings should be properly sealed and locked. Suitable vents, protected against outside contamination, should be provided. All effluent pipes should be properly sealed against leakage and tested by frequent inspections. Filtered water reservoirs should be thoroughly tight against external leakage, should be situated above the ground water table, and preferably should have no walls in common with any other plant units containing water in the process of treatment.

(8) Interconnections, Cross-Connections, Open Connections and Partition Walls

(*a*) No cross-connection or interconnection should be permitted to exist in a filtration plant between any conduit carrying filtered or postchlorinated water and another conduit carrying raw water or water in any prior stage of treatment.

(*b*) No conduit or basin containing finished water should be permitted to have a common division wall with another conduit or basin containing raw water or water in any prior stage of treatment.

(*c*) Rewash or filter-to-waste conduits should not be directly connected to any drainage conduit, but should be protected by a suitable one-way gap-delivery connection, so that no back-siphonage can occur under any condition.

(*d*) No conduit carrying raw water or any water in a prior stage of treatment should be located directly above another conduit carrying finished water, with a single common partition between them. This rule is not strictly applicable, however, to cast-iron pipes with tight joints carried in the open and readily accessible for inspection and repair.

(9) Drains

All drainage conduits should be constructed so as to be thoroughly tight against external leakage. They should discharge at points in a river or lake so located that no currents of water can under any circumstances be carried from a drain outlet to the plant intake, or to any other water intake located in the vicinity of the plant. No domestic or other sewer should be permitted to be discharged into the river or lake in the vicinity of a treatment plant intake, or directly above such intake, nor should any drain carrying contaminated surface water be permitted to be discharged likewise.

(10) Chlorination

(*a*) *General.*

Chlorination equipment should be selected, installed, and operated so that continuous and effective disinfection is secured under the required local conditions.

(*b*) *Chlorination equipment.*

1. Chlorination equipment should have a maximum capacity at least 50 per cent greater than the highest expected dosage to be applied at any time. It should be capable of satisfactory operation under every prevailing hydraulic condition at the plant.

2. Automatic proportioning of the chlorine dosage to the rate

of flow of the water treated should be provided at the larger plants and at all plants where the rate of flow varies more than 50 per cent above or below the average flow. Manual control should be permissible only where the rate of flow is relatively constant and an attendant is always at hand to effect promptly the necessary adjustments in dosage.

3. All chlorination equipment should be installed in duplicate, so as to provide stand-by units for insuring uninterrupted operation. Duplicate units should be operated frequently to insure workability. A complete stock of spare parts and tools should be maintained for emergency replacements or repairs.

4. A reliable and uninterrupted supply of water, free of coarse suspended mater, should be available under adequate pressure to insure the continuous operation of solution-free chlorinators. Hydraulically or electrically driven pumping equipment, if used for maintaining such pressure, should be provided with alternative sources of power where necessary to insure continuous operation.

5. Scales, preferably of the indicating and recording type, should be provided for weighing the cylinders of chlorine and checking the losses in weight of chlorine as fed from the cylinders during successive intervals of time. These scales should be sufficiently accurate and sensitive to measure such losses with suitable precision.

6. A sufficient number of cylinders of chlorine should be connected to the chlorinator in use so that adequate operating pressures will be maintained at various temperatures.

(*c*) *Hypochlorite solutions.*

1. Solutions of calcium or sodium hypochlorite should be prepared in a separate mixing tank, then diluted and allowed to settle, so that only a clear supernatant liquid is withdrawn to the solution storage tank and to the chlorinator.

2. The strength of stored calcium hypochlorite solutions should be checked frequently by laboratory test in order to ascertain that no loss of strength has occurred. Calcium hypochlorite solutions should be prepared freshly every 4 or 5 days, unless properly alkalinized with sodium carbonate.

(*d*) *Safety requirements.*

1. Suitable gas masks and a small bottle of ammonia for testing for leaks should be kept at convenient points immediately outside the room or enclosures in which chlorine is being stored or is in use. Gas masks should be inspected at regular intervals and kept in serviceable condition.

2. Chlorinating equipment and cylinders of chlorine should be housed preferably in separate buildings above the ground level, as a measure of safety.

3. The room or building housing chlorinators in service should be maintained at a temperature of above 60° F., but never in excess of the normal summer temperature. The cylinders of chlorine should be shielded, where necessary, from excessive heat or cold. Direct heat should not be applied to cylinders of chlorine, nor should hot water be poured over them or come in contact with the cylinder valve.

4. Adequate ventilation should be provided for all enclosures in which chlorine is being fed or stored.

5. All joints of tubing connecting chlorine cylinders and chlorinators should be kept absolutely tight and inspected frequently to insure tightness. Tubing should slope upward from the cylinders.

(*e*) *Control of chlorination.*

1. Chlorine should be applied continuously to the filtered effluent at a point where thorough and rapid mixing with the treated water will be effected. Free active chlorine should be in contact with the treated water for not less than 20 minutes, or chloramine preferably for at least 3 hours, before the treated water reaches the first consumer.

2. The proper dosage of chlorine will be determined by regular and frequent routine bacteriological and residual chlorine tests, both at the plant and at various points in the distribution system. In general, a safe desirable minimum of residual free chlorine at distant points in the distribution system would be 0.05 or 0.10 p.p.m., depending on circumstances. For chloramines, the desirable residual would be somewhat higher. The residual carried in the finished water as delivered from the treatment plant should be regulated accordingly. At times of threatened or prevalent outbreaks of water-borne disease, the residual chlorine should be increased preferably to a minimum of 0.2 or 0.3 p.p.m. in all parts of the distribution system, if possible, regardless of tastes or odors in the delivered water. Similar measures should be taken in the event of any lapse in the normal efficiency of the treatment plant.

3. Routine sampling points should be maintained at the treatment plant and at several vital points in the water distribution system. Sample collections should be made regularly at the latter points and the samples tested bacteriologically and for residual chlorine. Chlorine demand tests should be made occasionally on samples collected in the distribution system for comparison with the results of similar tests at the treatment plant. Any abnormal increase in the chlorine demand, or decrease in the residual chlorine at any point in the distribution system, should be checked and, if consistently observed, followed up by a thorough physical investigation of that portion of the system.

4. The tests for residual chlorine should be made in accordance with the eighth edition of the "Standard Methods for the Examination of Water and Sewage, 1936" published jointly by the American Public Health Association and the American Water Works Association. This test should be made at least once during each successive period of 8 hours every day in the finished water at the treatment plant and at least three times weekly at regular sampling points in the distribution system.

5. Special care should be taken to maintain a detailed and accurate record of chlorination and the results thereof. Such a record should show: rate of flow of water treated, gross weight of chlorine cylinder in use, weight of chlorine used for 24 hours, setting of chlorinator, and time of making and results of residual chlorine test.

6. Unless bacteriological and other tests should indicate the need of maintaining higher minimum concentrations of residual chlorine, at least 0.2 p.p.m. of free chlorine should be maintained in the treated water after a contact period of at least 10 minutes. When chloramine treatment is used for disinfection, the residual chlorine concentration, as indicated by the orthotolidine reagent, should be at least 0.4 p.p.m. after 2 hours of contact. Where "break-point" chlorination is practiced, a sufficient concentration of residual free chlorine should be maintained at the treatment plant so that it will be not less than 0.05 to 0.10 p.p.m. at all points in the distribution system. When required in specific instances, the minimum concentration of residual chlorine and the minimum retention period for the chlorinated water should be increased as directed by the State Department of Health.

7. Results of recent studies have indicated that the product of required concentration and period of contact of chloramine with water may range from 20 to 30 times the corresponding product for free active chlorine, in order to obtain comparable bactericidal action. The required dosage can be determined by means of "breakpoint" tests of the water and adjustment of the chlorine dosage so as to allow for some absorption of free chlorine in the distribution system initially. This absorption should diminish after the chlorine demand of organic matter remaining in the system has been satisfied.

C. Operation Control

(1) Supervision

Every water treatment plant engaged in purifying water for domestic use should be under the charge of a technically trained supervisor. For plants treating variable or highly polluted raw waters, trained supervision should be continuous and full-time. For certain types of small plants, part-time trained supervision may be practicable under favorable circumstances. Under these conditions, the supervisor should be in constant touch with the plant attendants and available on call in any emergency, and should visit the plant at least twice each week.

(2) Laboratory Tests and Control

(*a*) The schedule of laboratory tests followed in controlling the operation of a water treatment plant will vary with the size of the plant and character of water treated, though certain minimum requirements may be stated. For the ordinary plant, the minimum schedule of laboratory tests should include determinations of air and water temperature, turbidity or color (or both), alkalinity, pH value, hardness, residual chlorine, bacterial count at 20° C. or 37° C. (or both), and coliform bacterial numbers, both presumptive and confirmed. Where "break-point" chlorination is practiced, a continuous record of free ammonia in the water to be chlorinated should be maintained. Occasionally special tests may be necessary, such as for residual alum, iron, manganese, or other undesirable constituents of the final effluent. Where prechlorination is used in addition to post-chlorination, tests for residual chlorine should be made at each major stage of treatment and, in the raw water, tests for chlorine demand.

(b) For operation control at the plant, the frequency of tests, particularly for turbidity, residual chlorine, bacterial count, and coliform organisms, though dependent on the character of water treated and on its variability, should be such that at least one test each 24 hours and every day of the week will be carried out. For the larger plants, at least three sets of samples are usually collected daily for bacteriological tests. Determinations

of turbidity and residual chlorine are made more frequently, sometimes at hourly intervals when the character of the raw or partly treated water is changing rapidly.‡‡

(*c*) An important though somewhat less tangible element in judging the efficiency of plant operation is the general appearance of the plant and its surroundings. A neat, well-kept plant with attractive grounds is almost invariably an index of efficient operation, though, in some of the smaller plants especially, this criterion may not always be infallible. Mere neatness in the external maintenance of a plant, however, cannot offset lack of proper training on the part of the operator.

In rating the general efficiency of operation control, the following items are of primary importance:

(1) Training and experience of supervisor and operating staff.
(2) Adequacy of operation records.
(3) Efficiency of laboratory control.
(4) Suitability of plant design and construction to the character and pollution of the raw water.
(5) Capacity of the plant in relation to the average and maximum required output.

PART III

RECOMMENDED GENERAL SANITARY REQUIREMENTS FOR WATER DISTRIBUTION SYSTEMS

A. General

1. A water distribution system should be designed and constructed so as to provide at all times an adequate supply of water at ample pressure in all parts of the system.

2. The safety and palatability of the water should not be impaired in any manner while flowing through the distribution system, or any part thereof.

3. The system should be provided with sufficient valves and blow-offs so that necessary repairs can be made without undue interruption of service over any considerable area.

4. No unprotected open reservoir, or physical cross-connection whereby unsafe water can enter the distribution system, should be permitted.

5. The system should be tight against excessive leakage and its various mains and branches should be separated from rivers and other possible sources of contamination.

6. The system should be designed so as to afford effective circulation of water, with a minimum of dead ends.

7. The distribution system should be maintained in a sanitary manner, with due precautions against contamination of the water in any part of it as the result of necessary repairs, replacements, or extension of mains.

8. Frequent and regular bacteriological examinations should be made of water samples collected at various control points in the distribution system, with an immediate and thorough checking of any unusual results.

B. Piping System

1. The water mains should be of adequate size so that negative pressure will not occur under any condition of draft on the system.

2. Joints should be of such design and should be installed so as to show no leakage under a standard pressure test before covering. Materials used for caulking should be of a character such as not to foster the growth of coliform bacteria.

3. Corrective water treatment should be instituted where deposits in the mains tend to reduce the effective size and capacity of the pipes. For biological deposits, heavy chlorination may be effective.

4. The piping system should be designed so as to maintain an adequate positive pressure of water in all parts of the system, regardless of unusual drafts on any parts of the system. Pressure-equalizing standpipes or reservoirs should be located at suitably distant points from the pumping or main supply station.

5. Where dead ends are necessary as a stage in the growth of the system, they should be located and arranged with a view to connecting them ultimately so as to provide circulation.

6. Water pipes should be laid, so far as possible, above the elevation of nearby sewers and at least 10 feet laterally from them. Where this requirement cannot be met because of physical conditions, extra precautions should be taken in securing absolute and permanent tightness of water pipe joints.

7. Where a water service pipe crosses a street sewer at less than 6 feet vertically above the sewer, or is within 10 feet of it horizontally, all of that part of the water pipe lying within these distances should be constructed preferably of copper or brass pipe connected to the iron pipe with a brass fitting. In such cases it is preferable to use copper or brass pipe from the water main to the house, and the house sewers should be constructed of extra heavy cast iron with water tight joints. Where priorities necessitate the use of materials other than brass or copper, extra-heavy iron pipe should be used under these conditions.

8. Sanitary precautions should be taken in laying new water pipes. Where avoidable, pipe should not be laid in water or where it can be flooded with water or sewage in laying. Leakage tests should be made by means of hydrostatic pressure. New mains should be kept filled with a strong hypochlorite or chlorine solution (40-60 p. p. m. of chlorine) for at least 24 hours and then drained before being placed in service. Fire hydrants should not be drained into the sewers or storm drains. Valve chambers should be of watertight construction and should not be connected directly to a storm or sanitary sewer.

C. Cross and Open Connections

1. In general, no physical cross-connection should be permitted between a public or private water distribution system containing potable water and any other system containing water of questionable safety.

2. Open connections, physically separated, may be permissible under regulation and supervision by the local or State health department.

3. House or industrial toilet or sink fixtures capable of back-siphonage into the water system should be classed as cross-connections and should be prohibited, except where supplied by an independent elevated storage tank physically separated from the water supply pipes and protected by an approved siphon-breaker inlet. Dual water systems should be voided where possible.

PART IV

A. DISCUSSION OF CHEMICAL REQUIREMENTS FOR THE REVISED DRINKING WATER STANDARDS

It is fairly obvious that a water which is turbid, or colored to a degree which is easily noticeable, or which has an unpleasant or unsual odor or taste, will be looked upon with suspicion by the consumers to whom it is served for drinking purposes. For this reason its use should not be permitted where clarification of the water is practicable, or where a more acceptable supply is available.

The presence of considerable amounts of calcium and magnesium salts makes the water unsuitable to use for washing, and it is also unpleasant for drinking to persons who have been accustomed to softer water, but persons who are accustomed to the harder waters may find the softer waters less agreeable to their taste. Although it is open to question whether it would be justifiable to require the dilution of hard water by distilled water in order to keep within the limits specified in the Standards, it would be proper to require carriers to select the local supplies which most nearly fulfill the requirements of the Standards with respect to mineral content.

Insofar as the chemical composition of the water may cause inconvenience by its irritating effect upon the intestinal canal, or by any more serious effect upon well-being, the certifying authority will be justified in requiring that due regard be paid to this matter by common carriers. Unfortunately, it is difficult to secure reliable information concerning the physiological activity of salts as found in waters. Idiosyncracy is important. It is universally admitted that poisonous or otherwise harmful elements or salts in significant quantities, such as lead, hexavalent chromium, arsenic, fluoride or selenium, should not be allowed in water for drinking or culinary purposes. It is difficult, however, to fix limits for the less poisonous substances or salts which are normally present. The effect of sulfates, and especially of magnesium sulfate, is, however, well recognized, and it would be desirable to avoid the use of waters in which the concentration of these salts is sufficiently high to be annoying. The use of salts of barium or of hexavalent chromium for treating the water or water system should not be allowed on a drinking water supply. Molecularly

‡‡The following rule, wholly arbitrary, would give sampling requirements depending in part on the daily volume of water treated and on the density of raw water pollution.

N = number of samples per 24 hours,

where $N = \sqrt[4]{VC}$

V = volume of water treated in million gallons daily.

C = coliform number, M. P. N., in thousands per 100 ml.

According to this rule, the number of samples per 24 hours would range from 1 to 2 for a mgd. plant with raw water coliforms 1 to 5 thousands per 100 ml. and from 5 to 8 for a 100 mgd. plant with the same range in coliform numbers.

dehydrated phosphates have come into use for water treatment but sufficient information upon the physiological effects of small amounts of these salts is not available. Consequently, their use in excess of 10.0 p. p. m. for treating any drinking water should be avoided. When waters are treated with chemicals in order to soften or to purify them, it is desirable that any excess use of the chemical be avoided. Limits for alkalinity resulting from excess lime or other softening procedures already have been suggested. More than a small amount of free chlorine (1.0 p. p. m.) or chloramine (2.0 p. p m.) is objectionable in the effluent from a treatment plant because of resulting chlorinous taste in the water. In general, it is considered proper to insist that effort be made to find waters which are as satisfactory as possible from the standpoint of chemical characteristics, but with due regard to the region within which the water supply must be obtained.

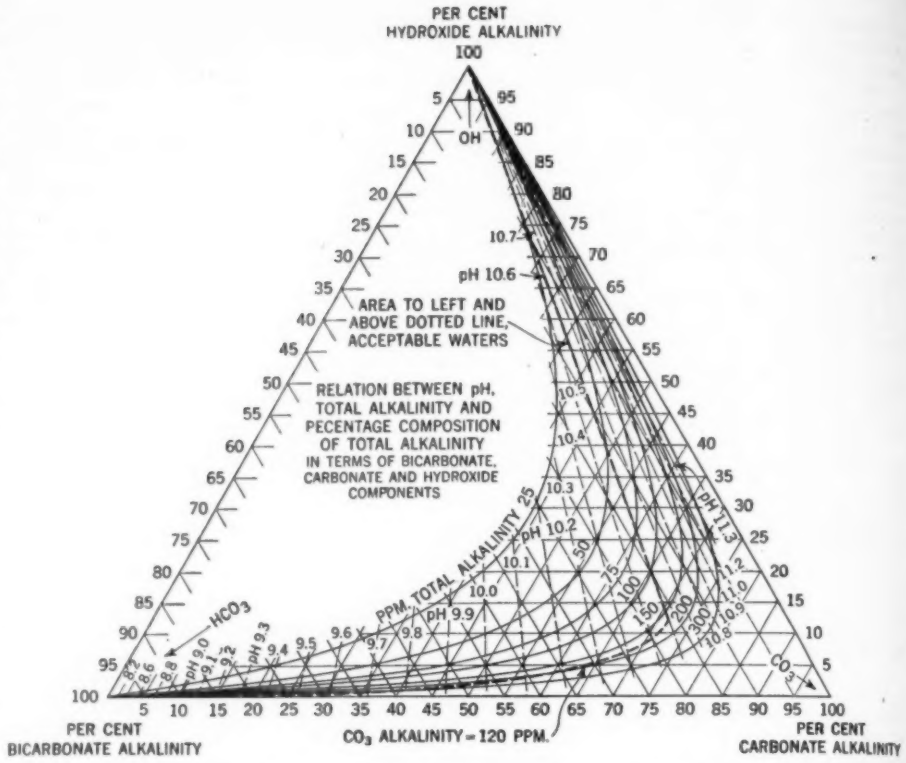


Figure 2.—Relation Between pH, Total Alkalinity, and Percentage Composition of Total Alkalinity.

Relation between pH, total alkalinity, hydroxide, carbonate and bicarbonate alkalinities in waters.—In the chemical analyses of water, it is often desirable to know the concentration of hydroxide, carbonate and bicarbonate alkalinities present in the sample, as well as the total alkalinity to methyl orange. At present, according to Standard Methods (4), the OH—, $CO{=}_3$, and $HCO{-}_3$ components of a total alkalinity are calculated from the values for the methyl orange (T) and phenolyhthalein (P) alkalinities by means of the relations given in part II, section VI, paragraph 3.1 (p. 66). Experimentally, the phenolphthalein titration of samples containing carbon dioxide and mixed carbonates is far from satisfactory. Furthermore, the formulae for calculating the amounts of OH—, $CO{=}_3$, and $HCO{-}_3$ alkalinity from the values of P and T ignore the laws of chemical equilibrium. The formulae assume that neither OH— and $HCO{-}_3$ nor $CO{=}_3$ and CO_2 may exist in the same solution, assumptions which are quantitatively incorrect. Also the formulae gives values for OH— which too often do not check with those calculated from the pH of the water.

On the basis of the ionization equilibria of carbonates and water, DeMartini (5) formulated equations by means of which the concentrations of CO_2, $HCO{-}_3$, $CO{=}_3$, and OH— present in a given sample can be calculated from the values for pH and total alkalinity. Moore (6), using the best available values for the ionization constants of carbonic acid and water, presents the DeMartini equations as follows:

(1) OH^- (in terms of $CaCO_3$) $= \dfrac{5\times10^{-10}}{(H^+)}$

(2) $CO{=}_3$ (in terms of $CaCO_3$) $\dfrac{5.61\times10^{-6}}{(H^+)}\times A$

(3) $HCO{-}_3$ (in terms of $CaCO_3$) $= 50{,}000\times A$

(4) CO_2 (as CO_2) $= 9.70\times10^{10}\times(H^+)\times A$

Where A is the factor $\dfrac{\dfrac{T}{50{,}000}+(H^+)-\dfrac{10^{-14}}{(H^+)}}{1+\dfrac{11.22\times10^{-11}}{(H^+)}}$

in which T stands for total alkalinity and (H^+) represents the hydrogen ion concentration and is related to pH by the expression

$$pH = \log\frac{1}{(H^+)}$$

The total alkalinity is an equilibrium mixture of its OH—, $CO{=}_3$, and $HCO{-}_3$ components. If the amounts of OH—, $CO{=}_3$, and $HCO{-}_3$ in a given alkalinity are expressed in terms of percentage of the total alkalinity, any given equilibrium mixture can be represented by a point on a triangular coordinate diagram. The triangular diagram has for its three coordinates the percent fractions of each of the three alkalinity components, OH—, $CO{=}_3$, and $HCO{-}_3$. These vary from 0 percent at the three sides of the triangle to 100 percent at the opposite apex.

Using Moore's equations, the amounts of OH—, $CO{=}_3$, and $HCO{-}_3$ in equilibrium with each other at pH values ranging from 7.0 to 11.6 for alkalinity values of 25, 50, 75, 100, 150, 200, and 300 p. p. m. were calculated, converted to the percent fraction basis and plotted on the triangular diagram. The curves show how the relative proportions of OH—, $CO{=}_3$, and $HCO{-}_3$ for any given alkalinity change with pH. In the diagram there are presented curves for waters with total alkalinities of 25, 50, 75, 100, 150, 200, and 300 p. p. m. (heavy solid line curves). The thin lines running from the base of the triangle to the opposite apex (100 percent OH—) represent samples of any given pH and show how for any given pH the relative amounts of OH—, $CO{=}_3$, and $HCO{-}_3$ will vary with total alkalinity.

The proposed Standards set the following limits: (1) the water shall not have a pH greater than 10.6, and (2) the carbonate ($CO{=}_3$) alkalinity shall not exceed 120 p. p. m. The thick broken lines represent these limits. All samples whose compositions are represented by points to the left of the 10.6 pH tie-line and above the 120 p. p. m. $CO{=}_3$ line are acceptable. All samples of composition represented by points to the right of and below the limiting lines are to be rejected.

Because chemical equilibria are affected by change in temperature and by changes in the ionic strength of the solution, Moore's equations are strictly valid only for waters at 25° C. and low dissolved solids concentration. (Ionic strength is more or less proportional to dissolved solids concentration.) However, for practical purposes the equations will hold quite accurately for all pH values up to 10.0 in waters containing up to 500 p. p. m. dissolved solids at temperatures from 15° to 25° C.

B. DISCUSSION OF BACTERIOLOGICAL REQUIREMENTS FOR THE REVISED DRINKING WATER STANDARDS

The bacteriological examinations which have come to be recognized generally as of most value in the sanitary examination of water supplies are:

(1) The count of total colonies developing from measured portions planted in agar or gelatin plates and incubated for 48 hours at 20° C.

(2) A similar count of total colonies developing on agar plates incubated for 24 hours at 37° C.

(3) The quantitative estimation of organisms of the coliform group by applying specific tests to multiple portions of measured volume.

Of these three determinations, the test for organisms of the coliform group is almost universally conceded to be the most significant because it affords the most nearly specific test for the presence of fecal contamination. Only this test has been included, therefore, in the bacteriological standard recommended, as neither the 37° C. nor the 20° C. plate count would appear to add information of sufficient importance, for the purpose of these Standards, to warrant their inclusion in the required examination. The omission of plate counts from the Standards is not to be construed, however, as denying or minimizing their importance in routine examinations made in connection with the control of water purification processes.

For the purposes of the Standards the coliform group is defined as including all organisms considered in the coli-aerogenes group as set forth in Standard Methods for the Examination of Water and Sewage, eighth edition (1936), as prepared, approved, and published jointly by the American Public Health Association and the American Water Works Association, New York City.

In accordance with this definition, the Standard provides that the procedure required for demonstration of the coliform group be as prescribed in Standard Methods, eighth edition, 1936, referred to above, for the tests designated:

(*a*) The completed test, or

(*b*) The confirmed test, when a liquid confirmatory medium (brilliant green lactose bile broth, 2 percent) is used, provided the formation of gas in any amount in this medium during 48 hours of incubation at 37° C. is considered to constitute a positive confirmed test, or

(*c*) The confirmed test where (1) crystal violet lactose broth, (2) fuchsin lactose broth, or (3) formate ricinoleate broth are used; providing the worker demonstrates the conformance of results, obtained with these three media, to the required conditions.

Moreover, it is recommended that this reference to Standard Methods shall be considered as applicable to all details of technique, including the selection and preparation of apparatus and culture media, the collection and handling of samples, and allowable intervals between collection and examination. As the standard procedure cited in this reference does not require differentiation between the various forms or types which are included under the general definition of the coliform group as given above, it has not seemed advisable, in the present state of knowledge, to require such differentiation in the application of the Standards. Two considerations tend to militate against the necessity or propriety of complicating the Standards by the incorporation of such differentiation. First, an analysis of the records of a considerable number of municipal water supplies during the past 20 years suggests that the coliform group has served effectively as an indicator of fecal pollution when the procedure for the determination of the coliform group was carried out in exact accordance with the methods specified. Second, competent research findings indicate that all constituent members of the coliform group are usually found in human fecal material. Consequently, it seems advisable to emphasize here a strict observance of the methods referred to, rather than to introduce any unnecessary procedures for the differentiation of the coliform group.

The principles involved in the quantitative interpretation of fermentation tests according to the "most probable number" concept, in multiple portions of equal volume and in portions constituting a geometric series, were discussed fully in appendix III of the Standards promulgated in 1925 and since then this discussion has been amplified by various authors. As these principles now are understood universally and enumeration procedures concerned are used quite widely, it has not appeared necessary to repeat this discussion in the current revision. The testing of multiple portions of equal volume affords a more precise measure of the density of the coliform group within a relatively narrow range of variation than does the testing of portions in geometric series. Therefore, as the waters which will be offered for certification should represent only a narrow range of very moderate pollution, the Standards require that the examination of each sample shall consist of the separate testing of five equal portions either of 10 ml. or 100 ml. each.§§ For laboratories which are equipped to make such tests, the examination of the larger, 100 ml., portions provides for: (1) a more definitive measure of the density of coliforms in the range of about 1 per 100 ml., as established by the Standards, and (2) information as to the approach of unfavorable conditions in the water.

The procedure for the examination of 100 ml. portions offers no difficulty in laboratory technique, the only additional requirements being larger containers, larger quantities of media, slightly greater incubator space, and the collection of a larger sample. If economy of incubator space is desirable, multiple-strength lactose broth may be used in conformity with the provisions in Standard Methods of Water Analysis. In practice it has been found satisfactory to use standard dilution water bottles of 160-180 ml. capacity as tubes or containers for the 100 ml. portions. These bottles, containing 30-35 ml. of quadruple-strength lactose broth and equipped with the ordinary inverted vial or with a Cowles (7) tube, are sterilized in the usual manner. For convenience in checking volumes, or to eliminate the necessity for the use of volumetric pipettes, the bottles may be graduated at the 35 ml. and at the 135 ml. points. This procedure lends itself readily to the planting of samples directly into lactose broth at the site of collection of the sample.

There is, of course, no essential reason why the number of portions tested should be five rather than some larger number, except that labor and materials are limited, and five portions are considered sufficient for such precision as is ordinarily necessary.

With reference to the total number of samples which should be examined, the intervals at which they should be collected, and the location of the sampling points on the distribution system, it is recognized that such requirements are affected by (1) the nature of the source of the water, (2) the character and the consistency of the treatment provided, (3) the sanitary conditions of the distribution system, (4) the average daily volume of water delivered to the distribution system, and (5) the total population served. It is obviously desirable, from the standpoint of precision and significance of results, to examine a large number of samples collected at frequent and regular intervals, and, when normal conditions obtain, preferably at uniformly spaced points on the distributing system, but when abnormal conditions exist, at such points as will produce the maximum information concerning the cause of any abnormalities in water quality. It is obvious also that it is not practicable to lay down hard and fast requirements adapted to the qualities of each supply in question. It has appeared desirable, however, to establish for the ideal supply a requirement for the minimum number of samples to be collected and examined during specific intervals, based on the population served, and to delegate to the inspecting officer, who should have knowledge of the conditions affecting the supply in question, the authority to increase the number of samples required and to fix the times and the sites for collection of samples on the distribution system.

In accordance with these principles, the first requirement stated in the Standards, namely, that "of all the standard 100 ml. or 10 ml. portions examined per month in accordance with the specified procedure, not more than 60 percent or 10 percent, respectively, shall show the presence of organisms of the coliform group," may be interpreted as implying that the mean density of organisms of the coliform group shall not exceed about 1 per 100 ml. The second clause of the Standards, which specifies that not more than 20 percent (or 5 percent when 10 ml. portions are examined) of samples tested (or not more than one sample if the whole number tested be less than 20 for 10 ml. portions or less than 5 for 100 ml. portions) shall show the presence of organisms of the coliform group in all five 100 ml. portions, or in three or more of the five 10 ml. portions, is more complex in its implications† and more difficult to explain. It recognizes that, according to the laws of chance, this result would occur in a certain small proportion of the samples tested, even though the mean density of organisms of the coliform group in the whole body of water tested actually remained constant at about 1 per 100 ml. or less and, consequently, that it warrants no inference of actual fluctuations in density unless it occurs with greater frequency than would be expected according to the theory of chance occurrences. A more frequent occurrence, sufficient to indicate occasional higher pollution, is believed, however, to be an indication of potential danger, even though the average quality of the water should be satisfactory (that is, in conformity to the first provision of the Standards). This clause of the Standards undertakes, therefore, to set a limit to the allowable frequency of positive results in an increased number of portions of any sample. It is necessary in so doing to recognize that water supplies actually do vary in their degree of pollution from day to day, and that in many instances the series of tests which will be considered may be small; hence, the limit (20 and 5 percent) is set at a frequency which is higher than reasonably might be expected in a large series of samples

§§ It is advisable, however, especially in the examination of waters of unknown quality or which may be suspected to be highly polluted, to make simultaneous tests in portions of a geometric series, ranging from 100 ml. to 1.0 ml. or less.

†This was ably discussed in appendix III of the 1925 Standards and this discussion has been amplified by various authors since that time.

from a water in which the actual density of organisms of the coliform group never greatly exceeded 1 per 100 ml. In the case of 10 ml. portions the limit for this frequency is set at 5 percent, which is approximately five times higher than the normal expectancy. With 100 ml. portions the requirement is somewhat more stringent as the 20 percent frequency allowed is only about 2.5 times higher than reasonably might be expected. As the possibility of an increase in pollution is ever present, the Standards provide further that when positive results are obtained in increased numbers of portions of any sample, additional and more frequent samples shall be collected and examined. The results from such additional samples will demonstrate whether the increase in positive results are due to the probabilities of chance, or to an actual increase in density of pollution.

In the bacteriological standard which has been promulgated, the committee has undertaken to set up two controlling factors: (1) two limiting values to the density of organisms of the coliform group, one limit applying to the mean density as calculated from the entire series of tests made during any one month and one to the range and frequency of occasional deviations from this mean, and (2) failure to conform with the specified procedures for making the bacteriological examinations may be used as the basis for a refusal of certification of a supply. That is, a failure to follow the specified procedures might produce results which would not provide for a satisfactory opinion of the quality of the water supply concerned.

REFERENCES

(1) Pub. Health Rep. 40: 693-721 (April 10, 1925).
(2) Manual of Water Quality and Treatment. American Water Works Association, 1940. Reprinted 1941.
(3) Public Health Bulletins 172 and 193; also Reprints 1114, 1170, 1292, 1434, and 1565 from the Public Health Reports, U. S. Public Health Service.
(4) Standard Methods for the Examination of Water and Sewage. American Public Health Association, 1936.
(5) DeMartini, F. E.: Corrosion and the Langelier calcium carbonate saturation index. J. Am. Water Works Assoc., 30:95 (1938).
(6) Moore, Edward W.: Graphic determination of carbon dioxide and the three forms of alkalinity. J. Am. Water Works Assoc., 31:51 (1939).
(7) Cowles, P. B.: A modified fermentation tube. J. Bact., 38:677 (1939).

CHART FOR CONVERTING GRAINS PER GALLON TO POUNDS PER MILLION AND THE REVERSE

Courtesy W. Donaldson and Fuller & McClintock, Engineers

POUNDS OF CHEMICAL REQUIRED PER HOUR FOR VARIOUS PUMPAGES & DOSES

PUMPAGE		DOSE - POUNDS PER MILLION GALLONS															
MILLION GALLONS 24 HRS.	THOUSAND GALLONS PER HOUR	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
		DOSE - GRAINS PER GALLON															
		.07	.14	.21	.28	.35	.42	.49	.56	.63	.70	.77	.84	.91	.98	1.05	1.12
1.0	41.7	.417	.833	1.25	1.67	2.08	2.50	2.92	3.33	3.75	4.17	4.58	5.00	5.42	5.83	6.25	6.67
1.5	62.5*	.625	1.25	1.88	2.50	3.13	3.75	4.38	5.00	5.63	6.25	6.88	7.50	8.13	8.75	9.38	10.0
2.0	83.3	.833	1.67	2.50	3.33	4.17	5.00	5.83	6.67	7.50	8.33	9.17	10.0	10.8	11.7	12.5	13.3
2.5	104	1.04	2.08	3.13	4.17	5.21	6.25	7.29	8.33	9.38	10.4	11.5	12.5	13.5	14.6	15.6	16.7
3.0	125*	1.25	2.50	3.75	5.00	6.25	7.50	8.75	10.0	11.3	12.5	13.8	15.0	16.3	17.5	18.8	20.0
3.5	146	1.46	2.92	4.38	5.83	7.29	8.75	10.2	11.7	13.1	14.6	16.0	17.5	19.0	20.4	21.9	23.3
4.0	167	1.67	3.33	5.00	6.67	8.33	10.0	11.7	13.3	15.0	16.7	18.3	20.0	21.7	23.3	25.0	26.7
4.5	187	1.88	3.75	5.63	7.50	9.38	11.3	13.1	15.0	16.9	18.8	20.6	22.5	24.4	26.3	28.1	30.0
5.0	208	2.08	4.17	6.25	8.33	10.4	12.5	14.6	16.7	18.8	20.8	22.9	25.0	27.1	29.2	31.3	33.3
5.5	229	2.29	4.58	6.88	9.17	11.5	13.8	16.0	18.3	20.6	22.9	25.2	27.5	29.8	32.1	34.4	36.7
6.0	250*	2.50	5.00	7.50	10.0	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0	32.5	35.0	37.5	40.0
6.5	271	2.71	5.42	8.13	10.8	13.5	16.3	19.0	21.7	24.4	27.1	29.8	32.5	35.2	37.9	40.6	43.3
7.0	292	2.92	5.83	8.75	11.7	14.6	17.5	20.4	23.3	26.3	29.2	32.1	35.0	37.9	40.8	43.8	46.7
7.5	312	3.13	6.25	9.38	12.5	15.6	18.8	21.9	25.0	28.1	31.3	34.4	37.5	40.6	43.8	46.9	50.0
8.0	333	3.33	6.68	10.0	13.3	16.7	20.0	23.3	26.7	30.0	33.3	36.7	40.0	43.3	46.7	50.0	53.3
8.5	354	3.54	7.08	10.6	14.2	17.7	21.3	24.8	28.3	31.9	35.4	39.0	42.5	46.0	49.6	53.1	56.7
9.0	375*	3.75	7.50	11.3	15.0	18.8	22.5	26.3	30.0	33.8	37.5	41.3	45.0	48.8	52.5	56.3	60.0
9.5	396	3.96	7.92	11.9	15.8	19.8	23.8	27.7	31.7	35.6	39.6	43.5	47.5	51.5	55.4	59.4	63.3
10.0	417	4.17	8.33	12.5	16.7	20.8	25.0	29.2	33.3	37.5	41.7	45.8	50.0	54.2	58.3	62.5	66.7
10.5	437	4.38	8.75	13.1	17.5	21.9	26.3	30.6	35.0	39.4	43.8	48.1	52.5	56.9	61.3	65.6	70.0
11.0	458	4.58	9.17	13.8	18.3	22.9	27.5	32.1	36.7	41.3	45.8	50.4	55.0	59.6	64.2	68.8	73.3
11.5	479	4.79	9.58	14.4	19.2	24.0	28.8	33.5	38.3	43.1	47.9	52.7	57.5	62.3	67.1	71.9	76.7
12.0	500*	5.00	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
12.5	521	5.21	10.4	15.6	20.8	26.0	31.3	36.5	41.7	46.9	52.1	57.3	62.5	67.7	72.9	78.1	83.3
13.0	542	5.42	10.8	16.3	21.7	27.1	32.5	37.9	43.3	48.8	54.2	59.6	65.0	70.4	75.8	81.3	86.7
13.5	562	5.63	11.3	16.9	22.5	28.1	33.8	39.4	45.0	50.6	56.3	61.9	67.5	73.1	78.8	84.4	90.0
14.0	583	5.83	11.7	17.5	23.3	29.2	35.0	40.8	46.7	52.5	58.3	64.2	70.0	75.8	81.7	87.5	93.3
14.5	604	6.04	12.1	18.1	24.2	30.2	36.3	42.3	48.3	54.4	60.4	66.5	72.5	78.5	84.6	90.6	96.7
15.0	625*	6.25	12.5	18.8	25.0	31.3	37.5	43.8	50.0	56.3	62.5	68.8	75.0	81.3	87.5	93.8	100.0

* Exact Values

1 grain per gallon = 143 pounds per million gallons = 5.95 lbs. per hour for each million gallons
0.70 " " " = 100 " " " " " = 4.17 " " " " " "

Courtesy Fuller & McClintock, Engineers

Example: What weight of Chemical must be fed each hour to give a 70 lb dose for a pumpage of 8.0 M.G.D. Opposite 8.0 M.G.D. and under 70 find 23.3, which is the correct weight.

Note: It is now becoming modern practice to record and report all chemical dosages in pounds per million (P.M.G.) and thereby have simplification in reporting and recording, rather than using the older scheme involving grains per gallon, parts per million, etc.

GRAVER TANK & MFG. CO., INC.

4809—43 Tod Avenue, EAST CHICAGO, IND.

NEW YORK CATASAUQUA, PA. CHICAGO TULSA

GRAVER WATER CONDITIONING EQUIPMENT

Aerators — Chemical Feeders — Clarifiers — Chlorinators — Water Filters — Taste and Odor Removal Filters — Iron Removal Filters — Oil Removal Filters — Swimming Pool Water Filters and Equipment — Filtering Material — Proportioning Equipment — Lime and Soda Hot or Cold Process Softeners — Zeolite Water Softeners

GRAVER HOT PROCESS DEAERATING WATER TREATING SYSTEM

This equipment removes scale-forming ingredients and corrosive dissolved gases from the boiler water supply, rendering the water suitable for use in high pressure boiler plants. Supplied as a part of the system are chemical feeders and proportioners, filters with non-siliceous filtering material and control valves, and auxiliary chemical feeders for after-treatment. Chemical feeders and proportioners are automatically controlled by the flow of water into the treating plant. Chemical charges can be varied to suit variations in quality and quantity of incoming raw water.

GRAVER ZEOLITE WATER SOFTENER

This type of equipment softens extremely hard water to zero hardness as determined by standard soap test. When water of zero hardness is not desired, blending with raw water automatically produces treated water of any desired degree of hardness.

Complete removal of dissolved solids from water supply for boiler feed purposes can be accomplished by Graver ionic exchange carbonaceous zeolite water softener.

This equipment can be furnished for manual operation using individual gate valves, or for semi-automatic operation whereby the various cycles are electro-hydraulically controlled by a push button, or entirely automatic operation, where all of the operating cycles are controlled automatically.

GRAVER CONTINUOUS LIME AND SODA WATER SOFTENERS

This equipment consists of settling and reaction tanks; chemical feeders, either solution or dry type; recarbonators for recarbonation of treated waters; filters, either pressure or gravity type; and all accessories for a complete system.

GRAVER WATER FILTERS

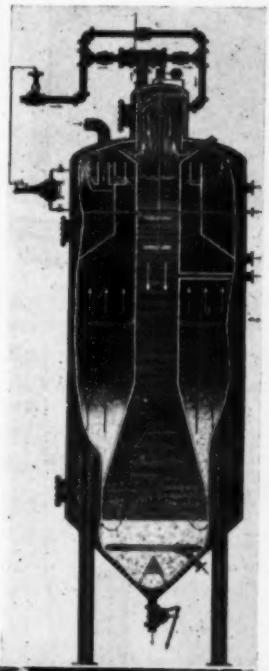
Graver Water Filters, either vertical or horizontal type, can be built in any convenient size. The filters are furnished complete with the necessary filtering material and all piping, fittings, and control valves arranged for filtering to service, backwashing to sewer, and rinsing to sewer. Graver Water Filters insure a supply of uniformly clear, filtered water that will meet the most rigid requirements.

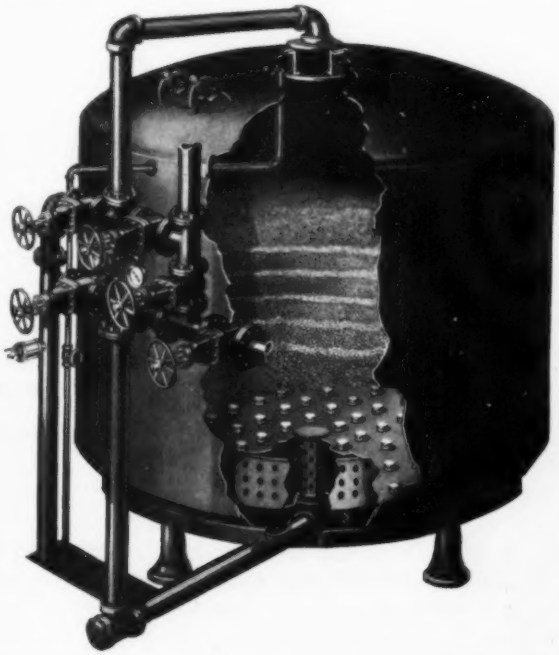
The hundreds of Graver Water Filters in use today in industries, institutions, and municipalities have demonstrated their exceptional efficiency as well as their low cost of operation and maintenance.

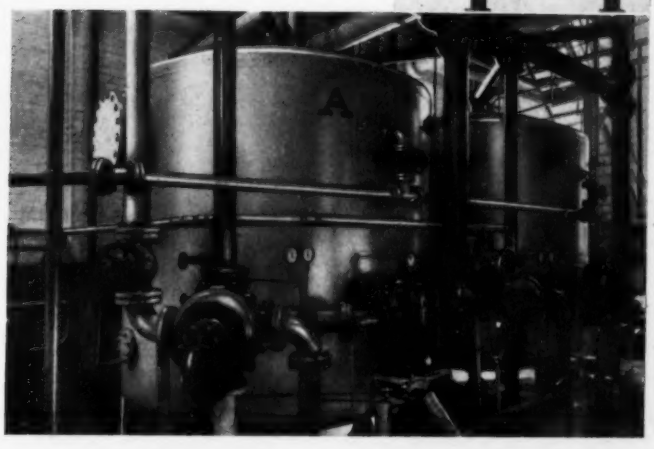
GRAVER SWIMMING POOL FILTRATION

Graver can supply complete filtration, recirculation, and sterilizing systems for the conditioning of the swimming pool water to meet the most rigid public health requirements. A complete Graver swimming pool system consists of pressure or gravity filters for the filtering of pool water, coagulant feeders, recirculating pumps, hair strainers, chlorinators, vacuum cleaners, pool fittings, water heaters, and pool accessories.

Graver engineers will gladly discuss your water conditioning problems with you and cooperate with your engineers in designing the equipment to meet your requirements.







Right—Graver Hot Process Water Softener with Deaerating Equipment.

Left, below—Graver Water Filter.

Right, below—Installation of Graver Zeolite Water Softeners.

See Our Advertisement on Sewage Treatment Equipment, Page 245.

HELLIGE

INCORPORATED

3718 NORTHERN BLVD., LONG ISLAND CITY, N.Y.

EQUIPMENT FOR THE COLORIMETRIC ANALYSIS OF WATER, SEWAGE, AND INDUSTRIAL WASTES

HELLIGE COLORIMETRIC COMPARATORS employ glass color standards which are non-fading, and therefore permanently reliable. There is no doubt whether these standards are "still good"; there is NO GUESSWORK. Hellige glass color standards never fade or change, never fail. Being made of colored glass, which has, for other uses, maintained its color stability for ages, they are the only standards which can logically carry a lifetime guarantee of accuracy. Glass standards are economical: bought once, they serve for practically an unlimited period, and thus quickly pay for themselves by the saving of time, chemicals, replacement cost, and other expenses encountered in the use of liquid standards. The standards occupy a minimum of space, and are the easiest to manipulate.

The comparators, with which the glass standards are used, are unique in design, and offer more conveniences than any other similar testing outfits. The improved model of Hellige Aqua Tester is shown at the left. The inclined construction for working in a natural sitting position, color fields in juxtaposition, and Nessler tubes with plano-parallel bottom plates are some features of this improved water tester.

The three small illustrations show the Hellige Pocket Comparator. It is the handiest and smallest instrument ever brought on the market for accurate hydrogen ion measurements and water analysis. The durable corrosion-resistant housing holds all parts necessary for a test, as revealed by the left and right hand illustrations which show the comparator with front and rear covers opened. The size of the complete apparatus is only 3¾ x 3¾ x 1½". For both comparators, glass color standards are available for all popular pH indicators, and for the determination of color of water, ammonia nitrogen, nitrate nitrogen, chlorine, iron, dissolved oxygen, manganese, lead, phosphate silica, and sulphides.

The HELLIGE TURBIDIMETER

A Turbidimeter *Without Standards* for Water Analysis and Sulfate Determinations

Illustrations show the observation fields: the one in the center shows the balanced field, after the proper adjustment of the slit by means of the drum knob; the end ones show the unbalanced fields.

This apparatus is based on the comparison of the Tyndall effect on the test liquid with a beam of light passing through the same suspension. Therefore, the use of standard suspensions which are tedious to prepare, and do not retain their original value, is entirely overcome. The comparison fields are distinctly differential so that measurements can be made with utmost convenience, simplicity, and speed, and correct results are obtained by anybody without special training for this type of work. Tubes of different liquid depths are available for turbidity measurements from 0 to 150 p.p.m. SiO_2, and sulfate determinations from 0 to 100 p.p.m. SO_4.

Write today for informative 28-page Bulletin No. 602.

CONTROL OF ALGAE

By FRANK E. HALE, Ph.D.

Director of Laboratories, Dept .of Water Supply, New York City.

Knowledge of microscopic organisms and their control is one of the more important aspects of water supply practices. Chief amongst agents utilized in algae control is copper sulphate, its application to reservoirs being known as "coppering."

The simplest manner of application is to drag burlap bags, containing about 50 pounds each, through the water by means of rowboats, taking a zigzag course so as to triangulate the surface of the water. Wind, waves, diffusion and gravity admix the streaks of treated water with the remainder. Crude as this method is, it has been found very effective. But it is essential that the chemical be well distributed.

[Recently there has been effectively used by the Los Angeles Water Department a mechanical broadcasting device on the rear of a launch. It distributes pulverized copper-sulphate over the water surface in a manner equivalent to that used in broadcasting fine grass seed. This method reaches shallow shore-line areas most effectively. See Jour. Review, Feby., 1936.]

The reservoir should be partitioned into arms by land sights and the capacity, in million gallons for total depth, calculated for each area so that dosage may be correctly apportioned. In the case of organisms predominating in the upper water, dosage may be calculated on the upper 20-30 feet only. About 3,000 pounds a day may be distributed by a single launch in favorable weather.

Calculation of the volume of a body of water is not difficult. Two formulas should be kept in mind:

One cubic foot contains 7½ gallons.

One gallon of water weighs 8⅓ pounds.

Estimate the area in square feet. Estimate the average depth in feet by soundings. Multiply the two for cubic feet. Multiply cubic feet by 7½ to find gallons and express in million gallons. In the table of treatment which follows one column reads directly in pounds of copper sulphate per million gallons of water to apply for each genus of organisms.

To calculate amount of copper sulphate needed from "Parts per million" column multiply million gallons by 8⅓ to obtain million pounds of water. Multiply this figure by the amount shown in the column headed "Parts per million."

Two formulas are helpful to bear in mind:

1 pound per million gallons = 0.12 part per million.

1.0 part per million = 8⅓ pounds per million gallons.

Copper sulphate may be fed to an aqueduct by continuous dry-feed to destroy organisms feeding from one reservoir to another. The effective dosage is identical with that employed in open reservoirs by the launch method.

Another frequently employed method of continuous feed of copper sulphate is by solution feed. On a small scale a wooden bucket may be suspended in the flowing water so arranged that its depth of submersion may be varied. A small hole in the bottom of the bucket admits the water. The bucket is filled with copper sulphate and a definite amount added once or twice a day and the depth of submersion regulated so as to dissolve the determined quantity each day.

Three to four hundred pounds per day may be fed by the barrel arrangement shown. By this equipment the chemical is applied as a saturated solution and the application is very uniform. The barrel is kept constantly full of water from a supply controlled by a float valve with glass ball. From the bottom of the barrel, through rubber, glass and copper tubing, the solution is discharged to the water at the most turbulent point. The flow is regulated by a pinch-cock. The barrel sets on a scale so that the weight of chemical delivered may be checked. The water consumed varies with temperature and other conditions from about 1¼ to 2½ gallons per pound of chemical dissolved.

Copper sulphate is very soluble in water. The following table may be useful in feed regulations at various water temperatures:

SOLUBILITY OF COPPER SULPHATE

Temperature: °C.	°F.	Pounds of Copper Sulphate Crystals ($CuSO_4 . 5H_2O$) Per 100 lbs. solution	Per 100 gallons water
0	32	19.5	126.0
10	50	23.1	226.8
20	68	26.9	269.4
25	77	28.9	296.1
30	86	31.3	326.1
40	104	35.2	371.1
50	122	39.1	433.7
60	140	44.5	521.3
80	176	55.5	717.2

Spraying with strong copper sulphate solution is advantageous in some instances, *e.g.*, in shallow bays and on floating masses of certain organisms. For this purpose a spray pump or equipment such as is used with insecticides for trees is available. [An alternate procedure is that used by Los Angeles to mechanically broadcast the pulverized sulphate previously mentioned.—Ed.]

Walls of basins have been sprayed for growths such as Spirogyra, using a 5 per cent solution.

Experience differs with waters of different composition, with temperature, and with amount of organisms present as to the right dosage to apply for each organism. About twice as much chemical is required in winter as in summer. It is a waste of chemical to apply an insufficient amount. If a smaller dosage fails, the entire larger dosage must be applied at one time. The water usually clears within three to four days when the correct quantity has been applied. [See Dosage Tables.] Weeds in general are not killed by copper sulphate. Sometimes fish are killed, but rarely in quantity. The following table indicates the susceptibility of fish to the chemical:

LIMITING SAFE DOSAGE OF COPPER SULPHATE FOR FISH

Fish	Parts per million	Pounds per million gallons
Trout	0.14	1.2
Carp	0.33	2.8
Suckers	0.33	2.8
Catfish	0.40	3.5
Pickerel	0.40	3.5
Gold Fish	0.50	4.2
Perch	0.67	5.5
Sunfish	1.35	11.1
Black Bass	2.00	16.6

Chlorine Treatment

Chlorination is the most valuable adjunct to copper sulphate in control of microscopic organisms. In the first place it helps destroy the odors set free by the copper sulphate treatment. In the second place it destroys many *genera*, in several instances the very ones least affected by copper sulphate.

The use of chlorine in increased dosage has slowly been extended not only to destroy organisms but also the distasteful oils. Experience to date indicates that with soft waters the following effects have been noted:

EFFECTIVE CHLORINE DOSAGES

Organisms Units per cc.	Chlorine ppm. Dose	Residual	Effect— Org. destroyed	Taste destroyed
Synura 1—25	0.3	.05-.10	Yes	Yes
Synura 50—100	0.5-0.7	.20	Yes	Yes
Synura 200	0.7-0.9	.30	Yes	Yes
Uroglena 2,000	0.5	.10	Yes	Yes
Uroglena 6,000	0.5	.10	Yes	No
Dinobryon 500	0.5	.10	Yes	Yes
Asterionella 1,350	0.7	.20	Yes (50%)	No
Aphanizomenon 1,500..	0.7-0.8	.20-.25	Yes (50%)	No

Prechlorination with high dosage, 1 ppm. and higher, is employed now quite extensively in conjunction with filtration to destroy or prevent growth of microscopic organisms in sedimentation and reaction basins and lessen their interference with filtration. Longer filter runs are obtained in addition to lightening the bacterial load upon the filters.

Miscellaneous Data. Cyclotella has been destroyed by dosage of 1 ppm. *Crenothrix* is another troublesome organism which is readily controlled by chlorine or chloramine in dosage of 0.5 ppm. Chlorine in dosage of 0.33 ppm. has readily controlled or prevented formation of jelly masses or fungus slime in well supplies and in mains and prevented clogging of condensers.

Crustacea, such as *Cyclops* and *Daphnia*, have been controlled on occasions. *Daphnia*, red variety, has been controlled with 1 ppm. chlorine and *Cyclops* with 3 ppm. chlorine.

The following table contains data brought up to date on dosages of copper sulphate and dosages of chlorine required for microscopic organisms, including also odors and tastes produced. It is based on published data and personal experience.

CHEMICALS REQUIRED FOR CONTROL OF DIFFERENT GENERA*

Organisms—Odor:	Copper Sulphate[1] Parts per million	Copper Sulphate[1] Pounds per mil. gals.	Chlorine ppm.
Diatomaceae:			
Asterionella‡	0.12*-0.20*	1.0-1.7	0.5*-1.0*
Aromatic, geranium, fishy			
Cyclotella†‡			1.0
Faintly aromatic			
Diatoma†			
Faintly aromatic			
Fragilaria†	0.25	2.1	
Melosira†‡§	0.20*	1.7	2.0
Meridion			
Aromatic			
Naviculat†	0.07	0.6	
Nitzchia§	0.50	4.2	
Synedra†‡	0.36*-0.50*	3.0-4.2	1.0
Earthy			
Stephanodiscus	0.33	2.8	
Tabellaria‡	0.12*-0.50*	1.0-4.2	0.5*-1.0
Aromatic, geranium, fishy			
Chlorophyceae:			
Cladophora†	0.50	4.2	
Closterium	0.17	1.4	
Cœlastrum†	0.05-0.33	0.4-2.8	
Conferva†	0.25	2.1	
Desmidium	2.00	16.6	
Dictyosphærium‡			0.5*-1.0
Grassy, nasturtium, fishy			
Draparnaldia	0.33	2.8	
Eudorina	10.00	83.0	
Faintly fishy			
Entomophora	0.50	4.2	
Glœocystis			
Offensive			
Hydrodictyon†	0.10	0.08	
Very offensive			
Microspora	0.40	3.3	
Palmella	2.00	16.6	
Pandorina	10.00	83.0	
Faintly fishy			
Protococcus			1.0
Raphidium	1.00	8.3	
Scenedesmus	1.00*	8.3	
Spirogyra†	0.12	1.0	0.7-1.5
Staurastrum	1.50	12.5	
Tetrastrum			1.0
Ulothrix	0.20*	1.7	
Volvox‡	0.25	2.1	0.3*-1.0
Fishy			
Zygnema	0.50	4.2	
Cyanophyceae:			
Anabæna‡	0.12*	1.0	0.5*-1.0
Moldy, grassy, vile			
Aphanizomenon‡	0.12-0.50*	1.0-4.2	0.5*-1.0*
Moldy, grassy, vile			
Clathrocystis	0.12*-0.25*	1.0-2.1	0.5*-1.0
Sweet grassy, vile			
Cœlosphærium‡	0.20*-0.33	1.7-2.8	0.5*-1.0
Sweet grassy			
Cylindrospermum	0.12	1.0	
Grassy			
Microcystis	0.20	1.7	
Oscillaria†	0.20-0.50*	1.7-4.2	1.1
Rivularia			
Moldy, grassy			
Protozoa:			
Bursaria			
Irish moss, salt marsh, fishy			
Ceratium†‡	0.33	2.8	0.3*-1.0
Fishy, vile, (rusty brown color)			
Chlamydomonas	0.50-1.0	4.2-8.3	
Cryptomonas	0.50	4.2	
Candied violets			
Dinobryon‡	0.18*	1.5	0.3*-1.0
Aromatic, violets, fishy			
Endamœba histolytica (cysts)			25.0-100 ^
Euglena	0.50	4.2	
Glenodinium	0.50*	4.2	
Fishy			
Mallomonas	0.50	4.2	
Aromatic, violets, fishy			
Peridinium	0.50*-2.00	4.2-16.6	
Fishy, like clam-shells			
Synura‡	0.12*-0.25	1.0-2.1	0.3*-1.0
Cucumber, muskmelon, fishy, bitter taste			
Uroglena‡	0.05*-0.20*	0.4-1.6	0.3*-1.0
Fishy, oily, cod-liver oil taste			
Crustacea:			
Cyclops†‡§			1.0 -3.0
Daphnia†‡§	2.00	16.6	1.0 -3.0
Schizomycetes:			
Beggiatoa†	5.00	41.5	
Very offensive decayed			
Cladothrix	0.20	1.7	
Crenothrix†‡	0.33 -0.5*	2.8-4.2	0.5*
Very offensive decayed, medicinal with chlorine			
Leptothrix†			
Sphaerotilis, natans†	0.40	3.3	
Very offensive decayed			
Spirophyllum†			0.25*
Thiothrix†‡			0.5*-1.0
Fungus:			
Achlya			0.6*
Leptomitus	0.40	3.3	
Saprolegnia†	0.18	1.5	
Miscellaneous:			
Chara†	0.10 -0.50	0.8-4.2	
Nitella flexilis†	0.10 -0.18*	0.8-1.5	
Objectionable			
Potamogeton†	0.30 -0.80	2.5-6.7	
Nais†			1.0*
Blood worm, chironomus†			15.0-50.0
Blood worm, gnats			3.0

The organisms where odors are expressed have been in sufficient quantity at one time or another to cause the characteristic odor.

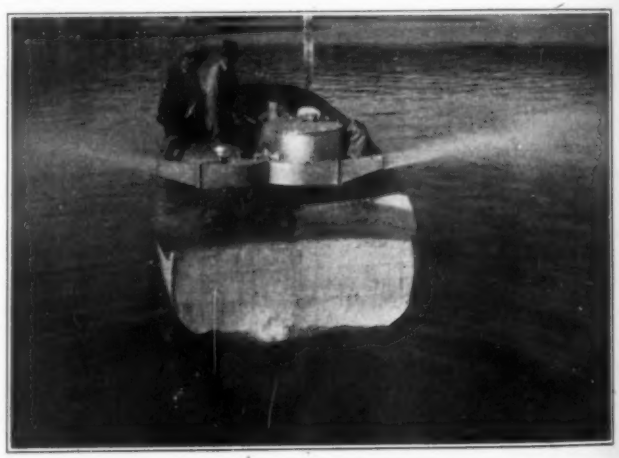
[1]The quality of water (hard or soft) and temperature has a decided influence on the requisite copper dosage. The harder the water, and the colder, the higher the dosage required. To under-treat is a waste of chemical and further—the whole dosage must be applied at one operation.

*Dosage successful in New York City's supplies.

†These organisms have caused trouble other than odor.

‡These organisms have been affected by chlorine producing characteristic odor and in many cases controlled by dosage ranging from 0.3 to 3 ppm., depending largely on amount of organisms.

§Controlled by excess caustic lime, 5 ppm., in the case of diatoms (48 hrs.).



Los Angeles' Improved Dry-Feed Coppering Machines Used in Algae Control, Surface Applications Have Proved More Economical and Effective. All Shallow Areas Are Reached Easily.

COPPER AND HEALTH

The effect of copper on health is a subject of such importance to all users of copper and brass and copper sulphate for algae control, that the conclusions in an article read before The New England Water Works Association* are given below:

1. The copper content of domestic drinking water after passing through copper or brass pipe or tubing, even if a slight amount of copper is taken into solution, is not harmful to health. It may indeed be beneficial.

2. All water supplies intended for domestic use after passing through a proper installation of copper or brass pipe or tubing will contain but a small percentage of the permissible copper content, if any at all.

3. The permissible copper content of domestic water based on a consumption of one gallon of water a day should apparently not be greater than 20 p.p.m.

4. It is unlikely that health will be injured by copper because, where the copper content is above 5 p.p.m., the taste of the water will generally be so disagreeable that it will be virtually impossible to **drink it.**

5. No anxiety need be felt about a proper installation of copper or brass pipe or tubing, because it has been shown that with acid water having a pH value of about 6.5, the copper content is generally only about 0.5 p.p.m., even after standing in the pipe lines for an appreciable length of time.

6. The treatment of reservoirs with copper sulphate to rid them of undesirable microscopic growths has no injurious effect on health.

*Journal N. E. W. W. A., 44: 4, December, 1930.

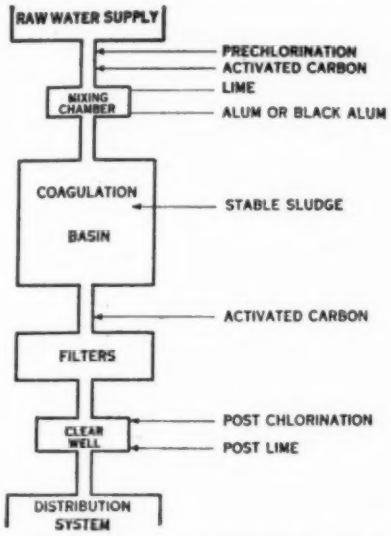
TASTE AND ODOR CONTROL WITH ACTIVATED CARBON

By E. A. SIGWORTH

Manager, Water Purification Dept., Industrial Chemical Sales Div., West Virginia Pulp and Paper Co., New York, N. Y.

ACTIVATED Carbon is a form of charcoal and, as used in water purification, is a very fine powder, or granular product. Since the finely powdered form is that most frequently used in water purification, the granular form will be eliminated from further consideration in this test.

Activated Carbon may resemble in appearance that of many other forms of carbon including charcoal, gas carbon black, etc. Therefore, it is not possible by a cursory examination to distinguish between an activated and an unactivated carbon. The true measure of an activated carbon is what it accomplishes in purification, and in the case of water purification this means its ability to remove odors and tastes. This removal is accomplished by concentration of impurities on the surfaces of the carbon particles. Thus an Activated Carbon may be considered as particles of carbon having a tremendous internal and external surface area which has been so purified as to eliminate any foreign materials clinging to the surface.



Flow Sheet for Chlorine and Activated Carbon Applications

Activated Carbons work by the physical phenomenon known as adsorption. By adsorption we mean the selective removal of materials from a solution, such as cloth picking up color from a solution when a dress is dyed. This should be distinguished from absorption such as is accomplished when water is soaked up by a sponge.

Methods of Application

Activated Carbon is usually applied continuously to a supply as the water passes through the purification system. In order to accomplish this, various proportioning devices of both dry and solution-type feeding have been employed successfully. Either solution or dry feeding equipment can be designed with sufficient accuracy to meet requirements in the water works field. The particular type of equipment to be employed for feeding depends upon the plant set-up, and individual preference. The dry feeding type of equipment is most frequently used because it involves less labor in feeding and control of the dosage. Many manufacturers have placed on the market feeding equipment specially designed for feeding activated carbon. It is suggested, however, that before purchase, the types of equipment be studied closely from the viewpoint of performance under all operating conditions.

Points of Application

Activated Carbon is insoluble and when added to water gives a black appearance. It is therefore evident that the carbon must be removed from the water before it enters the distribution system. Thus, carbon is usually applied ahead of sand filters. In normal water purification systems the points where carbon will logically be applied are; in the raw water, to the mixing basin, to the settling basin, or to the filters. Surveys have shown that the most common point of application for activated carbon is to the mixing basin, although each specific point of application has certain inherent advantages which must be taken into consideration in attempting to determine that point where best results will be accomplished. Furthermore, certain limitations may exist within individual plants preventing application at the point where best results might be expected.

First consideration must be given, therefore, to the specific design of the purification plant and a decision reached as to which points might be employed for the application. Factors which will play a part in such decisions are the degree of mixing of carbon with the water, and the mechanical design of the purification system. Carbon should not be applied where the water is in a relatively quiescent state since it will not disperse sufficiently to give contact throughout the entire body of water. Therefore, carbon should be applied at points where there is a restricted flow of water such as in mixing basins, near baffles in the settling basin, or to the filter influent.

Any point of application of carbon, whether before or after coagulation, has some advantages, and disadvantages. For example, where carbon is applied before coagulation, high dosages can be applied in order to take care of highly concentrated odors in a water supply. On the other hand, application of high dosages of carbon after coagulation might adversely affect the length of filter runs. Activated carbon when applied prior to coagulation partially settles out with the floc, resulting in a stabilizing action in the basins, thus decreasing the possibility of the water picking up odors due to decomposition within the water purification plant. Application of activated carbon to the filters is advantageous where odors have increased so suddenly as to get through the plant before they are noticed. Thus, application to the filters may save several hours of valuable time in controlling the odors. Furthermore, application in filters has been reported to be more economical because the odors at that point are less concentrated as a result of the effect of previous treatments.

There are so many inherent advantages to the various specific points of application that some operators have adopted the policy of applying carbon as a split treatment, part being applied to the water prior to coagulation and the remainder to the water after coagulation.

Effect of Other Chemicals

In any severe taste and odor problem it is advisable to consider the effect of other chemicals in order to determine the point of application of activated carbon which will accomplish maximum results. Because the effect of chemical treatment will vary quite appreciably within different plants, it is desirable that a study be made within the individual plant. Thus, any comments which we may make regarding the effect of other chemical treatments on odors must be considered as somewhat generalized statements. Aeration will normally accomplish an odor reduction of 10-15%, depending upon the efficiency of the aeration equipment and the concentration and type of odors. Coagulation appears to be a variable factor, since odors are sometimes increased and at other times are decreased. Actual experiences in plant operation are rather difficult to obtain because of the influence of activated carbon being utilized in the mixing basin. However, generally speaking it appears that coagulation does, in general, reduce odors to some slight extent, perhaps 5-10 percent. Filtration is also a rather questionable factor because of the influence of carbon within the treatment plant. As in the case of coagulation, the effect of filtration on odor is quite variable, reduction being very pronounced in some cases but slight in others. Perhaps a general all-around figure for the efficiency of filtration in reducing odors is approximately 10 percent. Thus the cumulative effect of various treatments of chemicals is relatively minor and cannot normally be considered as sufficient to correct a taste and odor condition in a water supply.

Dosages and Cost of Activated Carbon Treatment

Tastes and odors likely to be encountered in a water supply vary considerably. This can be readily understood when it is realized that tastes and odors may be caused by algae, decomposing vegetation, leaves, trade wastes, etc. In the case of algae alone, each of the many varieties frequently occurring in water supplies will give rise to odors peculiar to the specific type of algae.

Since these many odors are absorbed in different degrees by activated carbon, it is impossible to predict the dosage necessary. Furthermore, some odors are much more objectionable than others, even at extremely low concentrations. Cases have been reported where threshold odors as high as 30 have been considered palatable. Yet in one exceptional case many consumer complaints resulted from delivering water having a threshold odor of 2. In order to eliminate these complaints, it was eventually necessary to bring the threshhold odor on the delivered water to a value below 1.5.

Thus, in order to determine the carbonate dosage, it is first necessary to determine the extent to which the odor must be removed in order to render the water palatable. Following this, the carbon dosage necessary to accomplish the desired removal can be determined by employing various amounts in laboratory or plant scale tests. The average dosage of carbon being applied for eliminating tastes and odors will usually range from 20-40 lbs. per million gallons. However, as explained above, this should be considered as only an average figure since lower or appreciably higher dosages may be necessary. To give some idea of the different dosages necessary, let us consider two specific cases. In one water plant in the Mid-West it has been found that with threshold odors of 100 it is necessary to apply approximately 800 lbs. of activated carbon per million gallons in order to deliver a palatable water. In another plant in the Eastern part of the United States, actual experience demonstrated that with a threshold odor of 80 in the raw water a carbon dosage of 25 lbs. per million gallons resulted in delivering a palatable water to the consumer.

The actual cost of treatment is, necessarily, a variable factor, depending upon the quantity of carbon necessary. However, it is desirable that costs of treatment should be calculated on an annual basis rather than on periodic intervals when a severe taste and odor epidemic may occur. If calculations are on an annual basis it will be realized that periods of high carbon dosages will be offset by those periods when extremely small proportions are necessary. Therefore, on an annual basis it has been estimated that the average cost of activated carbon for taste and odor control would represent only approximately 3c per capita per year. Certainly such a low cost for delivering palatable water should be no hardship on any community.

Applications to Reservoirs

Thus far, consideration has been given to the use of activated carbon where sand filters are available for removal of activated carbon and adsorbed impurities. Many water systems, throughout the country, having no sand filters, are occasionally faced with taste and odor problems and, in a number of cases, activated carbon has been applied directly to reservoirs.

Where carbon is applied to reservoirs, provision should be made for a sufficient settling period in order to eliminate any appreciable quantity of activated carbon entering the distribution system. Therefore, where possible the reservoir should be taken out of service for two or three days in order to allow the carbon particles to settle to the bottom. In some cases it has been impossible to take reservoirs out of service, even for short periods of time, and in such cases activated carbon has been applied, taking care that the application is not made too close to the outlet gate.

The dosage of carbon applied to reservoirs is usually kept rather low, utilizing from 10-20 lbs. of activated carbon per million gallons of water in the reservoir. If this dosage does not render the water palatable, further treatment can be made after a week or two. Utilizing successive treatments for a reservoir has many advantages. In the first place, in the event any carbon does not get out into the distribution system small dosages will not be noticeable. Furthermore, from the labor point of view it is seasier to handle the smaller amounts of carbon utilized in the stage treatments.

In applying activated carbon to a reservoir, it is desirable to wet the carbon thoroughly before application since carbon particles have a tendency to float upon the surface of the water. The recommended procedure is that followed by Marshall S. Wellington in treating the Beaver Brook Reservoir at New Haven, Connecticut. He has described the method employed as follows:

> "Two one inch holes were bored on opposite sides of a fifty gallon barrel near the bottom. Glass tubing with an inside diameter of an ordinary pencil was inserted in the rubber stoppers and the stoppers in their turn inserted in the holes in the barrel. Small stoppers were then inserted in the other ends of the pieces of glass tubing. The barrel was then placed on the stern of a boat. This allowed the outlet ends of the glass tubing to remain about four inches above the surface of the water. The man power was distributed as follows: One man to add the activated carbon to the barrel and to keep it agitated. The second man to row the boat. The third man in the bow of the boat with a hydrant pump to keep a supply of water from the lake going into the barrel. The outlets on the glass tubes were made the proper size so that the man could keep the barrel full and yet not be overworked.
>
> "The carbon was mixed in a heavy soupy mixture in the barrel at the start, and when the boat arrived at the place to start treatment the small stoppers were removed and the mixture allowed to run out. The man at the barrel added fresh carbon when the mixture became too thin, while the man with the pump kept the barrel full. The boat was rowed in a similar manner as when Copper Sulfate was applied. This method allowed the carbon to be added in a continuous manner at a very fast rate. A very noticeable feature of this method was the fact that the mixture flowing from the glass tubes penetrated under the surface of the water before it started to spread. After the addition of the carbon was completed there was very little floating on the surface of the water."

Application of activated carbon to a reservoir in sufficient quantity to control tastes and odors appears to have quite a lasting effect as evidenced by the fact that treatment is usually not necessary for a period of two or more years. This may be due to the film of carbon which has formed on the bottom of the reservoir. Experiences in water purification plants have demonstrated the stabilizing influence of activated carbon on sludge decomposition and it is quite possible that the carbon on the bottom of the reservoir is exerting a similar influence. There is also a possibility that the black carbon film may have some tendency to discourage certain types of algae growths.

Although the original cost for treatment of a reservoir with activated carbon may be considered somewhat high, the possible extended influence of the carbon for long periods of time should demonstrate definite economy for this method of carbon treatment.

Blackout of Algae

The first application of activated carbon for algae blackout is credited to William P. Bailey at the City Water Works, Council Bluffs, Iowa. Although the successful use of activated carbon for algae control in settling basins was discovered by Mr. Bailey many years ago, it has only been recently that other plants have adopted this application. At the Council Bluffs plant, activated carbon was applied, not only to control algae, but also to remove odors. The amount of activated carbon necessary for taste and odor control was ample to accomplish algae blackout, consequently the most economical carbon dosage necessary to accomplish this blackout was not determined. It remained for Hartung and Lischer, St. Louis County Water Dept., St. Louis, Missouri, to determine the dosage of carbon necessary to treat a particular area of settling basins. At the St. Louis County Water Company plant, it was found that algae could be controlled at a dosage of approximately ¼ lb. per thousand square feet of area. Records reported by Bailey on operations at Council Bluffs, Iowa, show that the average carbon dosage was 1.47 pounds per thousand square feet. It should be realized, however, that this latter dosage was utilized to accomplish taste and odor control as well as algae blackout.

The method of application of activated carbon for algae control is somewhat similar to that recommended for reservoir application. The carbon is thoroughly wet and distributed over the surface of the basin once or twice a day. Since carbon is applied to exclude sunlight, it will be realized that application is not essential on cloudy days. Further details in the use of activated carbon for algae blackout are contained in a booklet entitled "TASTE AND ODOR CONTROL IN WATER PURIFICATION"*

*Gratis copies available from Industrial Chemical Sales Division, West Virginia Pulp & Paper Company, 230 Park Avenue, New York, N. Y.

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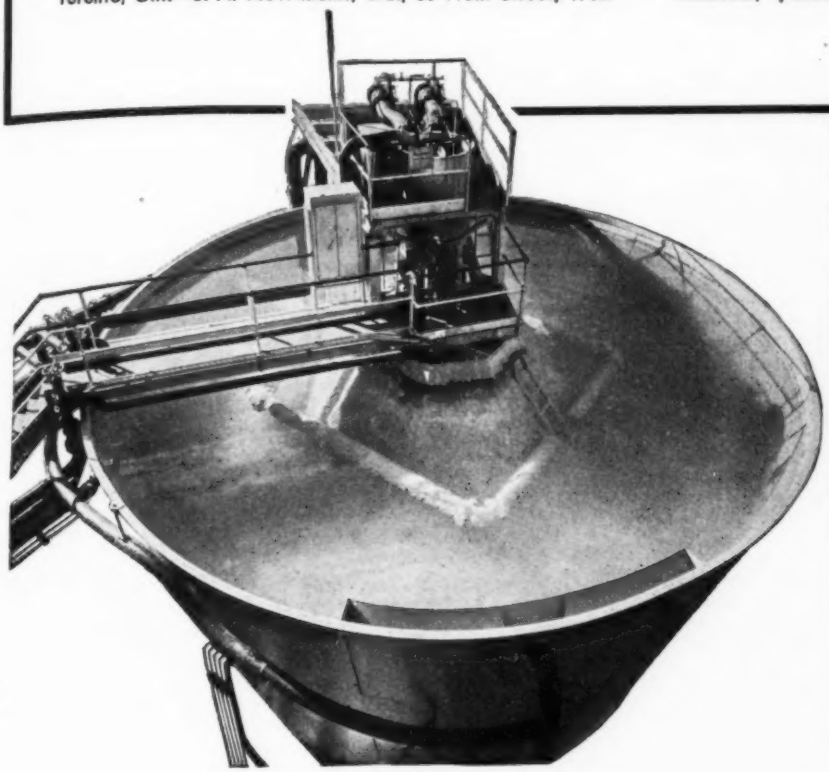

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WATER CONDITIONING HEADQUARTERS

WATER SOFTENING*

With Particular Reference to Its Economic Aspects

By CHAS. P. HOOVER

Superintendent of Purification

Columbus, Ohio

The consumer judges water to be hard if much soap is required to produce a lather, and soft if it lathers freely. The hardness of most water supplies is due to four compounds which are held in solution. These compounds are:

1. Calcium bicarbonate (solution of limestone, $CaCO_3$, in waters containing carbon dioxide, CO_2).
2. Magnesium bicarbonate (solution of magnesite, $MgCO_3$, in waters containing carbon dioxide, CO_2).
3. Calcium sulphate (in the form, $CaSO_4.2H_2O$, is known as gypsum).
4. Magnesium sulphate (in the form, $MgSO_4.7H_2O$, is known as epsom salts).

As long as any of these compounds or a combination of them are present in a water supply it is hard.

Chlorides and nitrates of calcium and magnesium are sometimes present.

Calcium and magnesium bicarbonates were formerly designated as temporary hardness, but are now termed carbonate hardness.

Calcium and magnesium sulphates, chlorides, and nitrates were formerly designated as permanent hardness or incrustants, but are now usually called non-carbonate hardness.

Water softening processes remove objectionable iron compounds and manganese as well as hardness.

In general terms, hard water is made soft by a treatment which changes calcium and magnesium compounds from a soluble to an insoluble form, and then by removing the insoluble compounds by sedimentation and filtration, or by an exchange process, which consists in replacing the calcium and magnesium with sodium. The first process is known as the chemical, or lime-soda process, and the second, the zeolite process.

[Elsewhere in this issue appears a map of the United States which reveals the average hardness of public water supplies of important American municipalities, of each State.—*Ed.*]

History

The art of water softening with lime dates back to the year 1766 when Cavendish discovered that the addition of lime to natural water caused a deposition of the carbonates of calcium and magnesium. The proposal to use lime for softening hard water on a plant scale was advanced by Thomas Henry in England about 1800, but it was not until 1841 that water softening on a large scale was developed by Dr. Thomas Clark of Aberdeen, Scotland. He patented the process of adding lime to water to precipitate earthy carbonates held in solution by carbonic acid.

Winnipeg, Canada, built the first municipal plant in 1901. In 1903, the first municipal plant in the United States was built at Oberlin, Ohio.

In 1908, water softening on a larger scale than had hitherto been tried was undertaken at Columbus, Ohio, when a plant having a capacity of thirty million gallons per day (now 50 m.g.d.) was constructed.

For years the advantages of water softening were offset to a certain extent by disadvantages. Difficulties arose in operating sand filters on account of incrustation of the sand with calcium carbonate. Water mains, service pipes and meters became clogged with heavy deposits. When water contained an excess of causticity it was unpalatable. The recarbonation process developed by Archbutt and Deeley in the latter part of the last century, was employed at several plants in England for the purpose of overcoming all the above difficulties, but its first employment in this country, on a successful plant scale, was in 1921 at Defiance, Ohio. Since that time practically all water softening plants have been equipped with recarbonation devices.

The chemistry of water softening is now well understood, and an exact prediction of the results to be obtained can be made. Improvements in design and equipment for applying chemicals and removing sludge all tend toward simplifying operation. As a result of these improvements there has been a decided trend toward some degree of water softening by municipalities throughout the United States. Industry has gone forward with water softening to a far greater extent because of proven economies in processes, materials and equipment where soft water is made available.

Economic Aspects of Water Softening

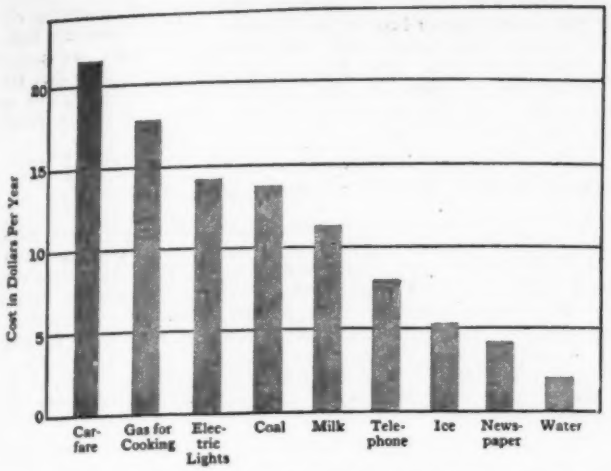
The water supply in a large number of cities and villages should be softened because:

1. Hard water destroys soap; makes household work more difficult; has a bad effect on clothes washed in it, on plumbing, heating systems, boiler tubes and shells; and is unsuitable for many industries.
2. Softening at a central source of supply rather than in thousands of homes is economically sound.

It is cheaper to pay a reasonable additional charge for centralized softening than to accept a hard supply, a portion of which must be softened in the home. All of us, whether we

* Excerpts from "Water Supply and Treatment"—written by Mr. Hoover and published by the National Lime Association.

The Water Softening Plant of Fort Wayne, Indiana



Cost Per Capita Per Year for Domestic Services (Family of Five)

know it or not, soften some water each day, for it is necessary to use soft water to keep clean.

All public water supplies contain some hardness and that portion of the water in which soap is used must be softened to be effective. Soap has very little cleansing action until it lathers and it will not lather until the hardness salts in the water have been neutralized by it.

Aside from the objections of the precipitated soap curd, the extravagance of removing hardness with soap can be appreciated when it is realized that a pound of lime costing approximately one-half cent will neutralize as much hardness as 20 pounds of soap costing approximately $3.00.

Soap Losses Determined Experimentally

The amount of soap consumed and the quantity of water used for household processes, laundering, dish-washing, cleaning, washbowl activities, and bathing, was carefully measured for a period of one week, and calculated for a year.[1] Two kinds of water were used, each for one week: (1) Scioto River water which was filtered and sterilized but not softened. The hardness was 270 parts per million (16 grains per gallon). It was delivered in 10-gallon bottles to the home where the experiments were made. (2) Softened water as delivered to consumers. The hardness averaged about 80 parts per million (4.7 grains per gallon). In the home where the experiments were made there were five people, three adults and two children. Ivory soap in bar and flake form was used, the former costing 21 cents per pound and the latter 31 cents. The laundering was done in a vacuum type electric washer, the weight of the clothes averaging 29 pounds per washing.

Water-works records show that this family used the average quantity of water, about 30 gallons per day per capita. Their bill amounted to 75 cents per month. The soap was dried and weighed before and after it was used, so that the difference in weight would represent the weight actually used. The results for the week figured to one year show:

1. That this family used 281 gallons of water a week for ordinary household cleaning, divided as follows: Laundry, 15 gallons; dish-washing, 73 gallons; cleaning, 4 gallons; bathing, 136 gallons; and washing of hands, 53 gallons.
2. That approximately 11.46 pounds of soap were used per week with unsoftened water, or a total of 596 pounds per year.
3. That approximately 3.7 pounds of soap were used per week with Columbus city softened water, or a total of 192.5 pounds per year.
4. That softened water saved this family 403.5 pounds of soap per year.
5. That this soap, valued at 20 cents per pound, represented a saving of $80.70 per year and figured at 12 cents a pound, the price of cheaper laundry soaps, represented a saving of $48.42.
6. That this consumer could afford to pay five or six times as much for softened as for unsoftened water.

The investigation also disclosed the following facts:

1. One-half again as much time was needed to launder clothes in the unsoftened as with the softened water.
2. The cleanliness of clothes washed in the unsoftened water was not entirely satisfactory. Several very soiled pieces had to be rewashed and all of the clothes had to be re-rinsed.
3. The general appearance of the clothes was unsatisfactory.

These figures may be high for the average family but they are fairly representative for a family of five living in moderate circumstances. There are 55,033 domestic services or consumers in Columbus, Ohio. Applying the above figures, if each one saves $48.42, the total saving would amount to $2,664,697.86. If this figure is divided by two because of the possible use of cheaper compounds to "break" the water, the saving would be $1,332,348.93. This amount is about eight or ten times the cost of chemical softening.

Relations of Soap Wastage to Quantity and Type of Water

The above experiment demonstrated that 8 gallons of water per day per person were used for household processes. This quantity was probably not all completely softened by soap. Other workers have made the following estimates of water completely softened per capita per day:

	Gallons
Foulk[2]	0.9
Report of Special Committee for Madison, Wis.	1.7
City of St. Louis[3]	1.0
Average	1.2

The amount of soap required to reduce the hardness of 1,000 gallons of water, one part per million, has been determined as being 0.2 of a pound (Foulk's formula: Pounds of soap consumed per 1,000 gallons $= 2 + 0.2H$).

Based on these assumptions, the loss per family of five using water of varying degrees of hardness is shown in the following table:

SOAP WASTAGE AND COST WHEN USING WATER HAVING HARDNESS VARYING FROM 150 TO 500 PARTS PER MILLION

Raw water hardness p.p.m	Hardness removed by softening	Hardness reduced to	Loss lbs. of soap per family of five per yr.	Loss per family of five per year*
150	65	85	28.5	$3.40
200	115	85	50.0	6.00
250	165	85	72.5	8.70
300	215	85	94.0	11.30
350	265	85	116.0	13.90
400	315	85	138.0	16.55
450	365	85	160.0	19.20
500	415	85	182.0	21.85

*Soap at 12 cents per pound.

Actual Survey of Retail Soap Sales

The economic effects of quality of water, with special reference to soap consumption in the home, were demonstrated by H. W. Hudson[4] in a field survey of retail soap sales in four cities of the middle west: Superior, Wisconsin, and Bloomington, Champaign-Urbana, and Chicago Heights, Illinois. A canvass of all retail stores selling soap in these cities was made by a personal investigator who compiled a complete record of soap sales. The soap sales and per capita soap consumption with different types of water are shown in the following tables:

TOTAL SOAP SALES IN FOUR CITIES

City	Annual soap sales, pounds	Annual soap sales, dollars
Superior, Wisconsin	1,530,314	$196.133
Bloomington, Illinois	1,517,658	215,528
Champaign-Urbana, Illinois	2,093,881	307,732
Chicago Heights, Illinois	1,009,503	159,910

PER CAPITA SOAP CONSUMPTION WITH DIFFERENT TYPES OF WATER

City	Total hardness of water supply p.p.m.	Annual per capita soap consumption pounds	Annual cost of soap per capita dollars
Superior, Wisconsin	45	29.23	$3.75
Bloomington, Illinois	70	32.13	4.48
Champaign-Urbana, Illinois	298	39.89	5.93
Chicago Heights, Illinois	555	45.78	7.50

[1]Thesis presented for the degree of Master of Science by Miss Pauline Snyder, Ohio State University, 1927.

[2]Geological Survey of Ohio, Bulletin 29, 1925.

[3]Report of Water Commission, 1922.

[4]Abstract of thesis for Doctor of Philosophy in Economics, University of Illinois, 1933.

The results show.

1. That soap bills increase as the hardness of the water with which soap is used increases.
2. That even with a relatively soft water, a considerable quantity of soap is required to remove dirt and grease.
3. That by taking Superior as a basis for comparison, the annual per capita soap waste is: Bloomington, 2.9 lbs.; Champaign-Urbana, 10.7 lbs.; Chicago Heights, 16.6 lbs.
4. That this loss in Chicago Heights would amount to $15.00 per year per family of four.

From the results of this study an equation was formulated to show the degree of hardness necessary in any particular water supply in order that the economy in soap obtainable by the use of soft water would pay for the cost of softening.

$$X = \frac{C - 75D + 75F}{F - D}$$

X = hardness of water supply in p.p.m., the softening of which will be paid for in soap economy alone.
75 = demonstrated attainable hardness of water in p.p.m., from municipal water softening plants.
F = soap waste per capita per year per p.p.m. hardness.
C = capital overhead charges, including superintendence, per capita per year.
D = cost of chemicals per capita per year per p.p.m. hardness.

Mr. Hudson states that if this equation is applied to data for Champaign-Urbana and the hardness of the raw water tested only 145 p.p.m. (it is actually 298 p.p.m.) a municipal water softener that would soften the water to 75 p.p.m. would save enough in soap for home use alone to pay for itself.

Effect of Hard Water on Power and Heating Systems

Heating hard water causes it to deposit scale in water pipes, heating coils, boiler tubes, and boiler shells. The heat loss due to scale, 1/50 to 1/9 inch thick, has been computed to be from 7 to 16 per cent.[5] This means that with scale 1/9 inch thick, 16 cents of every dollar paid for coal is lost. This is in addition to the trouble, cost of drainage, and time lost in getting rid of the scale. According to an estimate of the American Railway Engineering Association,[6] the damage caused by one pound of scale is 13 cents. The Association further estimates that the improvement in operating and maintaining locomotives, due to water softening, amounts to a saving of from $4,000 to $9,000 per locomotive per year.

Hard Water Stunts Growth of Cities

A study of ten Illinois cities shows[7] that eight have comparatively soft water supplies as judged by midwestern standards, whereas the other two have supplies that are excessively hard. The two hard water cities will be designated as A and B. Both are situated in rich agricutural sections and are advantageously located with respect to large markets. In spite of these advantages they have shown a very slow rate of growth. In 1880, A and B together had 26 per cent of the total population of the ten cities. In 1920 they together had only 13.7 per cent.

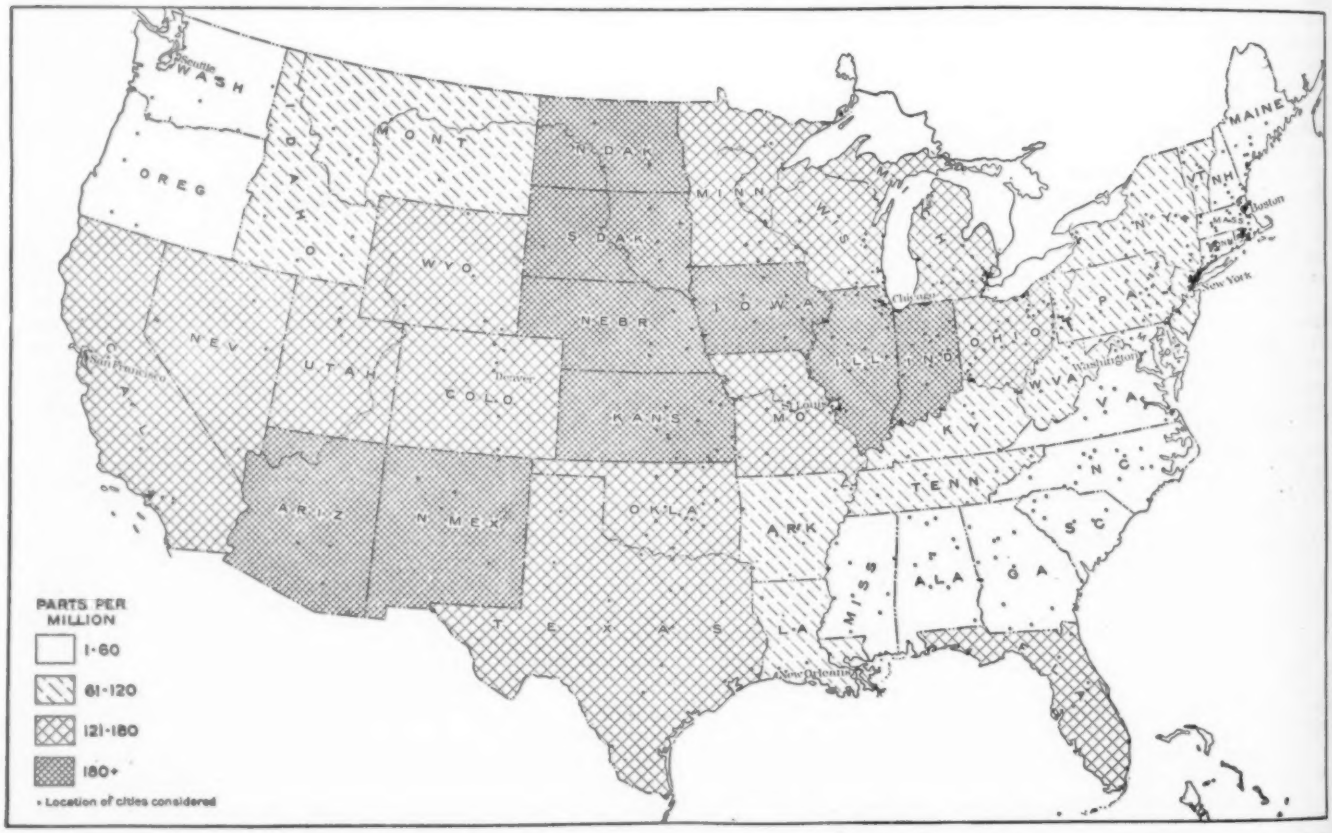
Manufacturing industries which require soft water for their successful operation, in establishing plants select communities having satisfactory water, other things being equal.

Cost of Softened Water vs. Other Commodities

"Cheap as dirt" is a common expression, but even expensively treated water is *much* cheaper! Two hundred and forty-one gallons of water equal one ton. Five cents a ton would be a little over 20 cents per 1,000 gallons, which is more than the average consumer pays for water in the larger and medium sized cities. A ton of dirt delivered would cost many times this amount.

The cost per capita per year for various domestic services by a family of five in Columbus, Ohio, is shown in the chart on the preceding page.

[5] U. S. Bureau of Mines, Tech. Paper 218.
[6] Bulletin, American Railway Engineering Association, November, 1923.
[7] Alvord, Burdick & Howson (Chicago), a private communication.



Weighted Average Hardness, by States, of Water Furnished in 1932 by Public Supply Systems in Over 600 Cities in the United States (Reprinted from U. S. Geol. Survey Water Supply Paper—658)

Fig. 1.—Annual Soap Consumed per Capita for Waters of Various Degrees of Hardness

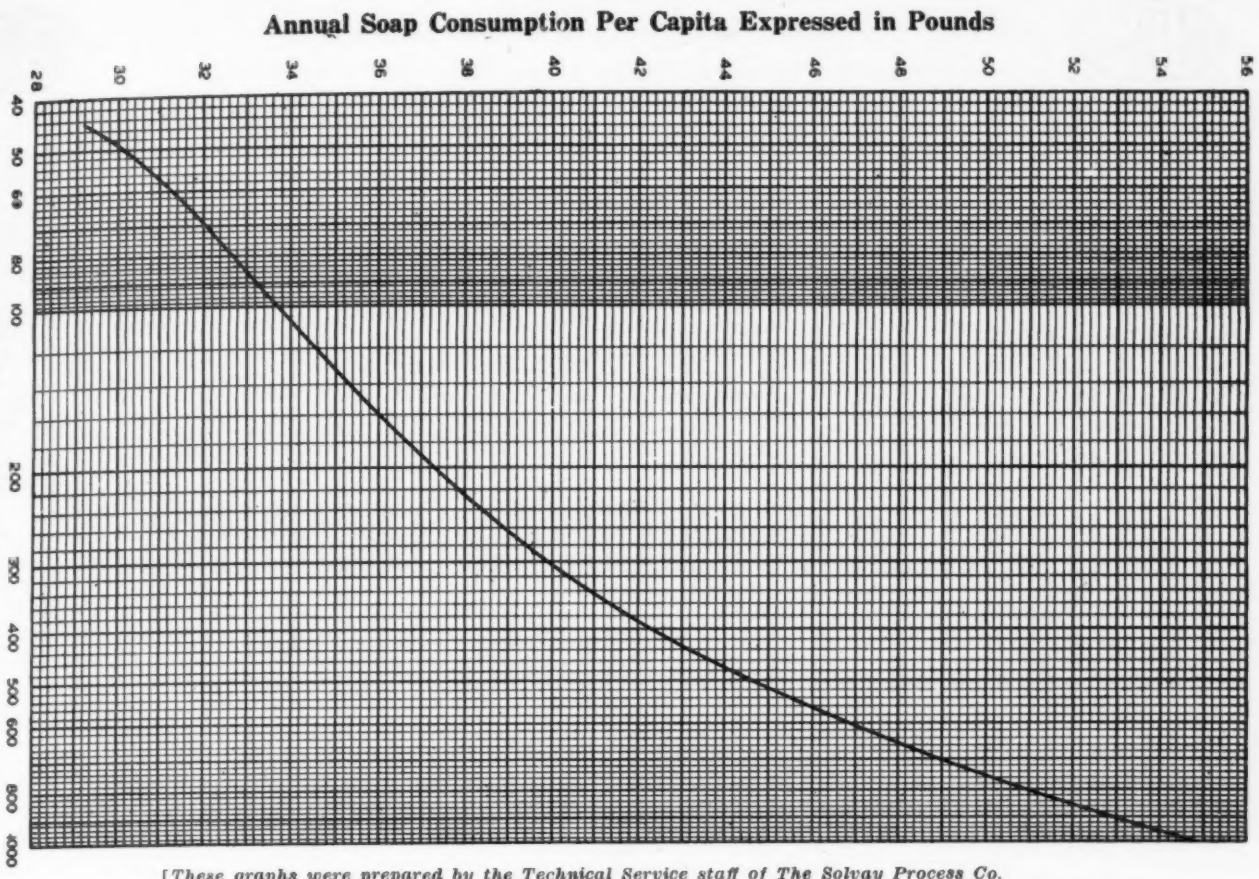

Annual Soap Consumption Per Capita Expressed in Pounds
28 30 32 34 36 38 40 42 44 46 48 50 52 54 56
Hardness in Water Supply
Expressed in Parts Per Million of $CaCO_3$
40 50 60 80 100 200 300 400 500 600 800 1000

Fig. 1.—Annual Soap Consumed per Capita for Waters of Various Degrees of Hardness

[These graphs were prepared by the Technical Service staff of The Solvay Process Co. from soap consumption data compiled by H. W. Hudson and published in the A.W.W.A. Journal—Vol. 25, p. 645, 1933. These graphs and other valuable information on water treatment appear in Solvay's Technical Bulletin No. 8.]

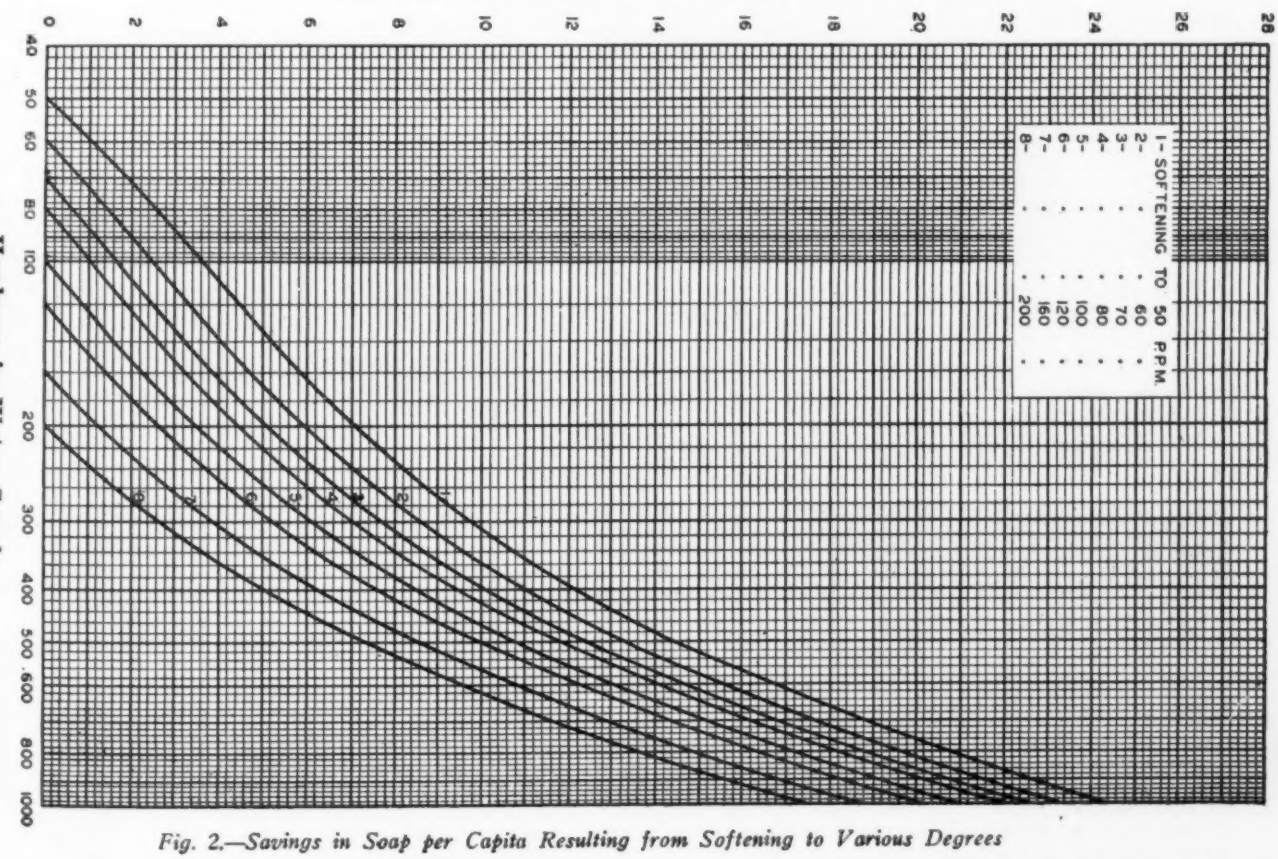

Annual Soap Savings Per Capita Expressed in Pounds
0 2 4 6 8 10 12 14 16 18 20 22 24 25 28
Hardness in Water Supply
Expressed in Parts Per Million of $CaCO_3$
40 50 60 80 100 200 300 400 500 600 800 1000
1- SOFTENING TO 50 P.P.M.
2- 60
3- 70
4- 80
5- 100
6- 120
7- 160
8- 200

Fig. 2.—Savings in Soap per Capita Resulting from Softening to Various Degrees

INFILCO INC.

(Formerly International Filter Co.)

Water Conditioning, Sewage Treatment, Hydraulic Control and Chemical Feed Equipment

325 W. 25TH PLACE, CHICAGO, ILL.

PRODUCTS

Aerators—MultiCone, forced draft, coke tray, cascade and spray
Boiler Water Purification Plants
Carbon Purifiers—Taste, odor and color removal plants
Chemical Feeders—Dry and solution types, combination mixers and feeders
Color Removal Plants
Controllers—Chemical feed, rate of flow, liquid level, hydraulic valve
Filters—Concrete and wood gravity, pressure, and disk type water filters; also oil removal, swimming pool, etc.
Filter Plant Equipment—Controls, gauges, indicators, recorders, operating tables, transfer switches, coagulators, etc.
Fluorine Removal Plants
Gauges—Rate of flow, liquid level, etc.
Iron Removal Plants
Lime Feeders and Slakers
Proportioners—Acid and chemical feed
Sewage Treatment Equipment—Activators, Accelo-Filters, coagulators, clarifiers, dosing siphons, rotary distributors, samplers
Silica Gels
Softening Plants—Lime-soda, Hot-flow, Accelator, Zeolite.
Steam and Gas Purifiers
Sterilizing Equipment
Swimming Pool Equipment—Filters, cleaners, fittings, etc.
Taste and Odor Removal Plants
Venturi Tubes
Water Filters and Filter Plant Equipment
Water Softening Plants of all types
Zeolites and Zeolite Water Softeners

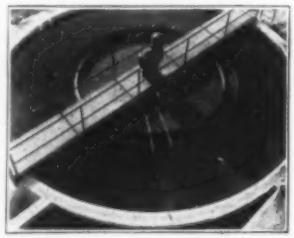
WATER CONDITIONING EQUIPMENT

INFILCO SERVICES

INFILCO has specialized in the design and manufacture of all kinds of water conditioning equipment—from aerators to underdrains—for over forty years.

The consulting engineer or his client can specify "Infilco" throughout the water treating plant knowing that such equipment has the benefit of Infilco's vast experience in supplying thousands of installations. Specifying one brand of equipment throughout gives the added assurance of undivided responsibility and coordinated results. The services of Infilco's staff of competent engineers and their complete laboratory facilities, ready to cooperate in making recommendations and reports, are at the disposal of the consulting engineer or his client.

ACCELATOR SOFTENERS AND CLARIFIERS

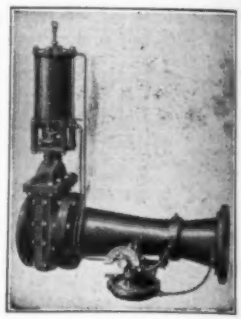


The Accelator for water softening and clarifying is one of the most important water treatment developments in recent years. While retaining all of the advantages found in the conventional lime or lime-soda processes, it offers many new advantages. Treating, mixing, reaction and clarification, all are carried out in an incredibly small space. Treating chemicals are applied in a new way. Reactions occur under new conditions. Size is but a fraction of that for old type plants where design was based upon holding time requirements for chemical and physical reactions and for sedimentation.

ZEOLITES AND ZEOLITE SOFTENERS

Infilco Zeolite Softeners are of either pressure or gravity type, and are built in sizes to meet any capacity requirement. Controls are furnished for either manual, semi-automatic or full automatic operation as desired. A variety of Infilco Zeolites are available, and the selection of type to be used will depend upon the characteristics of the water to be softened and upon requirements. All Infilco Zeolites are capable of quick regeneration, considerable overload capacity and operation at high rates of flow.

CONTROLLERS AND GAUGES



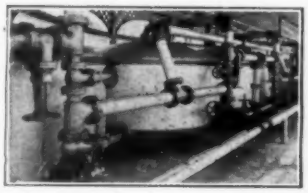
Infilco Rate of Flow Controllers, for automatically maintaining uniform rates of flow, are noted for their accuracy, low loss of head, reset and rate setter features. Infilco Water Level Controllers operate hydraulically controlled valves to maintain proper liquid levels.

Infilco Indicating and Recording Rate of Flow, Loss of Head and Liquid Level Gauges and Illuminated Indicators provide visual indication and permanent records of plant operation.

PRESSURE AND GRAVITY FILTERS

Clean, clear water, essential for municipal supply, is assured by Infilco pressure or gravity type filter plants, in capacities from a hundred gallons per day up.

The design of every Infilco filter plant is based upon sound engineering principles, backed by over four decades of experience in equipping many hundred municipal water works, and building tens of thousands of industrial filters.



RECARBONATORS

Infilco Recarbonators are available for the stabilization or recarbonation of industrial liquids, trade wastes and lime-softened water. Infilco equipment provides for the complete process of producing, cooling, scrubbing, compressing, drying and applying carbon dioxide gas to the liquid.

COAGULATORS

Infilco Coagulators promote economy and efficiency in the chemical treatment of water and sewage. The applied chemicals are fully utilized by bringing them into intimate contact with the liquid undergoing treatment. The suspended particles are collected rapidly and quickly aggregate into masses having very high subsiding values.

TRANSFER SWITCHES, OPERATING TABLES ROBOTROLS AND SAMPLING TABLES

Infilco Transfer Switches provide finger-tip control of hydraulically operated mechanisms. They meet every requirement of 4-way plugs or piston cocks without their inherent disadvantages. Extreme compactness is obtained by grouping all four separate valves in one body, along with pressure and waste passages.

Infilco Operating Tables offer both utility and a pleasing appearance. They provide centralized and simplified control for a number of hydraulically operated valves, and at the same time furnish an attractive mounting for the control levers, indicators and gauges.

The Robotrol is a robot filter or softener operator. It backwashes (or regenerates) and returns the unit to service—automatically, efficiently and without supervision.

Sampling tables furnish a visual check on the condition of raw, settled and filtered water.

HYDRODARCO PURIFIERS

Hydrodarco is the activated carbon made expressly for water purification. Hydrodarco Purifiers, employing beds of granular Hydrodarco, automatically remove tastes, odors, chlorine, iron, organic color, etc. They are furnished in capacities from a few gallons per hour to millions of gallons per day.

INFILCO FILTER UNDERDRAINS

Wagner Filter Underdrains provide a primary distributing system of a manifold and laterals on wide centers, with distributing orifices along their undersides; and a secondary system of Wagner precast blocks fitting between the laterals. The system fills every requirement for perfect wash water distribution. With manifold and laterals of Transite (an asbestos and Portland cement product) this underdrain is practically everlasting.

FLUOREX PURIFIERS

Fluorex is a specially prepared, highly porous and reactive tricalcium phosphate for removing fluorine from water. Fluorex Purifiers, with their improved method of regeneration wh ch prolongs the active life of the adsorbant and makes possible the use of ordinary materials and construction, offer the ideal means of removing fluorine.

AERATORS

To permit selection of the proper type of aerator to meet conditions of head and space available, character and quantity of water to be handled, and the results desired—Infilco offers its MultiCone, forced draft, coke tray, floating cone, adjustable cone and cascade aerators.

CHEMICAL FEEDERS AND PROPORTIONERS

Infilco Chemical Feeders—dry or solution—provide means for volumetrically or gravimetrically measuring and feeding chemicals in any form: liquid, powdered, granulated or lump. Capacities are from a fraction of a pound to hundreds of pounds per hour.

Infilco Continuous Lime Feeders and Slakers combine in one continuous, automatic process, the consecutive operations of feeding and slaking crushed or pebble quicklime, followed by the preparation and delivery of a suitable milk of lime mixture.

Infilco Proportioners maintain predetermined ratios between liquid or solid flows, or automatically vary the ratio of one flow with respect to another, by electric, hydraulic or mechanical means.

SEWAGE TREATING EQUIPMENT

INFILCO manufactures equipment for all sewage treating processes—chemical, biological and mechanical. In offering many products for application in these various processes, Infilco also offers the user the advantage of centralized responsibility, which is important in assuring continued satisfactory equipment operation.

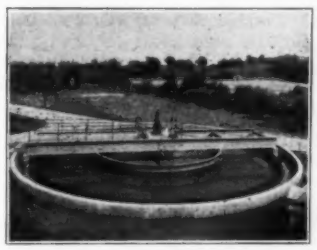
For making recommendations and reports to the consulting engineer and his client, Infilco extends its laboratory facilities and the service of its staff of engineers. It is of course not intended that this service shall conflict with the work of the engineer; rather, it is meant to be in cooperation with this work.

ACCELO-FILTER SYSTEMS

The Accelo-Filter system provides a new and improved method for treating sewage and organic wastes by constant, *direct* recirculation through the trickling filter. This results in repeated inoculation with freshly aerated material and provides effective reduction of the organic content of the biological filter at a considerably higher dosage rate.

Aero-Spray Nozzles on a rotary distributor (above) provide a fan-shaped variable spray which assures optimum coverage and maximum aeration in the application of screened, settled sewage to trickling filters. All parts of these improved nozzles are bronze to assure long life.

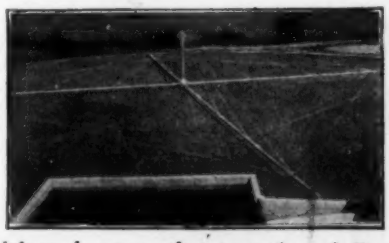
CLARIFIERS



Infilco Types WS and PD Clarifiers obtain a perfect balance of the conditions necessary for efficient operation of a sewage concentrator. These Clarifiers are designed with curved rotating scraper blades that gently concentrate and remove settled material with practically no disturbance of the liquid. Accordingly, retention periods may be selected to avoid both septic action and excessive surface scum formation.

The two different sizes of Infilco Clarifiers assure effective removal of solids from the sedimentation tank whether it be small or large. The WS Clarifier with central motor reducer drive is supplied for tank diameters up to 40 feet. For diameters larger than 40 feet, there is the PD Clarifier, driven by a horizontal motorized reducer through a pinion which meshes with a stationary rack at the tank periphery.

ROTARY DISTRIBUTORS AND DOSING SIPHONS



Only Infilco Rotary Distributors offer so many important refinements such as full-opening arm end gates, mercury seal with protective seal ring, and corrosion-resistant nickel iron castings, along with low operating head requirements and uniformity of distribution. Infilco dosing siphons insure perfect operation of distribution mechanism at all flow rates.

OMEGA MACHINE CO.

3409 East 18th St., Kansas City, Mo.

REPRESENTATIVES

Atlanta, Ga.—W. D. Taulman, 610 Red Rock Bldg.
Chicago, Ill.—A. J. Foley, 7309 East End Ave.
Detroit, Mich.—Wm. A. DaLee, Inc., 4835 Woodward
Hawaii—Alan Duvall, Box 33, Honolulu
Los Angeles—Chas. P. Crowley, 711 Gibbons St.
New York City—Triangle Equipment Co., 50 Church St.
Philadelphia, Pa.—Alan A. Wood, 2045 N. Broad St.
Toronto, Ontario—Control & Metering, 454 King St. West
Brazil—Oscar Taves & Co., Box 840, Rio de Janeiro
Colombia—MacDonald & Peterson, Ltd., 502 Banco de la Republica, Bagota.
Argentine—Fiore Co.—Paseo Salon—Buenos Aires

EQUIPMENT

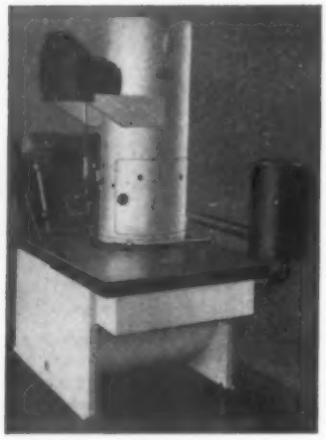
For Dry Material

Loss-in-weight type Gravimetric Feeders
Belt type Gravimetric Feeders
Weighcheck Feeders
Universal Volumetric Feeders
Disk Feeders
Dust Removers and Filters
Combined Bucket Elevators & Feeders

For Liquids

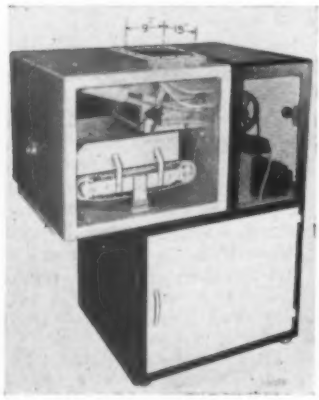
Precision Feeders
Rotodip Feeders
Proportioning Pumps
Laboratory Stirrers
Lime Slakers
High Speed Agitators
Slow Speed Agitators
Automatic Proportional Control

LIME SLAKERS



OMEGA continuous Lime Feeders and Slakers are available in sizes from 175 pounds per hour, as illustrated, to 10,000 pounds per hour. Slakers are insulated multi-compartment type and equipped with heat exchanger coils for high temperature, efficient operation. Water jet operated dust and vapor removal devices prevent clogging of the feeding mechanism. Operation may be made completely automatic.

BELT TYPE GRAVIMETRIC FEEDER



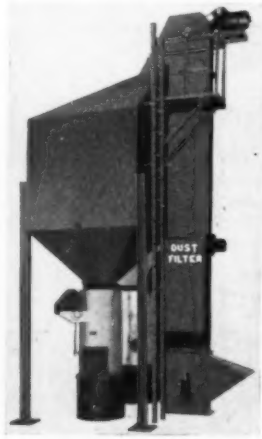
Weighs the material continuously on a short 20" conveyor belt which is carried on accurate sensitive scales. Astonishingly simple and rugged. Feeder may be bolted directly to storage bin or supplied by chute. Feeding range 5 pounds to 6,000 pounds per hour. A totalizer shows the pounds of material delivered by the feeder. Automatic control of "flooding" and automatic fluid proportioning controls available.

UNIVERSAL FEEDER

Rugged, accurate, dependable Volumetric Feeder. Three sizes available. May be used with extension hopper.

The illustration shows automatic proportioning feeder with lead lined dissolving chamber—stainless steel high speed agitator and Rotameter on water supply. These accessoris recommended for feeding Ferrisul, Ferrifloc, and low grade Alum. The make-up tank is used when pumping solution to a higher elevation.

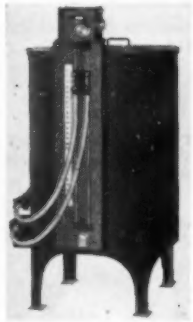
COMBINED FEEDERS—ELEVATORS—STORAGE BINS—BIN GATES AND DUST FILTERS



Complete chemical feeding systems are engineered and built to fit the job. The illustration includes the following equipment—all designed and built by OMEGA:

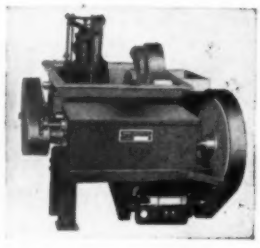
Universal Feeders—Size No. 2.
Storage Bin—Double Outlet.
Bin Gates—Slide Type.
Elevator and Platform.
Dust Remover and Filter.
Hopper Agitator.

PRECISION FEEDER



The most accurate and simplest type of Volumetric feeder for solutions or light suspensions. Rate of feed set by dial to desired percentage or gallons per hour. Feeding range from 1/25 to 400 gallons per hour. For any feeder the range is 100 to 1. Feeding mechanisms furnished for customer's tank. Tanks may be wood, steel, lead or stoneware. Standard tank sizes—15, 25, 50, 75, 100, 200 or 400 gallons. Not an orifice feeder but a true Volumetric feeder. For Calgon, Hypochlorite, Ferrisul, Ammonium Sulfate, etc.

ROTODIP METER



For feeding from large supply tanks which may be located at a distance from the feeder. Feeding range 1 to 800 gallons per hour. Galvanized, rubber covered or plain steel construction. Variable speed drive gives an infinite number of speed changes from zero to maximum rate. Liquid feeders and dry feeders may be accurately synchronized to make up fixed strength solutions or suspensions.

LABORATORY STIRRER

For jar tests, to determine proper coagulant or carbon dosages. Also ball mill or tumbler type for agitating material in closed vessels, for threshold treatment tests.

LIME AND LIME SLAKING

By H. E. LORDLEY
Plant Manager, Department of Public Utilities
Richmond, Va.

LIME is one of the oldest chemicals known to civilization, yet today the efficient utilization of this important chemical is impeded by lack of complete information concerning its physical and chemical properties. Since lime is used in such large quantities for softening and corrosion control in the water works field, it is amazing that so little information is to be found in water works literature on the subject of lime and lime slaking.

There Is Lime and Lime

Limestone, which is the source of the calcium oxide, will vary in physical and chemical properties in different parts of the country. Some limestone is high in magnesium which is objectionable for use in water purification plants, yet suitable for other chemical processes. Other sources are high in iron and silica, so it is well to study an analysis of the raw stone before buying lime for the water plant. At the lime plant, in the first step of processing the rock for calcining, a superoir finished product results if mud, sand, and other impurities are removed before burning. In the actual calcining step, the manufacturer can control both the physical and chemical properties of the lime, either by the type of kiln or the method of firing. Therefore, we get much lime that is either under-burned or over-burned by lack of control of the process at the kiln.

Take, for example, the old style vertical kiln using coal as a source of heat without modern control equipment, we find that the lime thus burned will slake very slowly. On the other hand, the modern controlled rotary kiln produces lime that will slake so rapidly that it actually explodes in the slaker. The author recalls an amusing incident at the Richmond Filter plant on changing from a vertical kiln to a rotary kiln lime. The operator frantically called to report that the lime slaker was out of order and making a terrible rumble in the slaking chamber. On investigation, the new rotary kiln lime was producing miniature explositions that sounded like a loose agitator blade. Also common to the old style vertical kiln is the large percentage of core as compared to practically core-free lime from the rotary kiln. So we see that all lime is not the same from every lime plant and the water works executive must choose the source of lime carefully if highest efficiency is to result.

As to Lime Properties

After the lime leaves the kiln it must be graded as to size. Quicklime can be furnished in sizes varying from a fine pulverized product, which will pass a 200 mesh screen, to a pebble lime of two inch size. In determining the proper size to use in the plant, the operator must remember that the pulverized lime offers both a dust problem and a feeding problem due to arching in the hopper. Dust can be controlled by proper ventilating system, but archhing is just a universal worry. Arching can be partly corrected by design of light weight hoppers having a bottom slope of not less than 60° from the horizontal. "Syntron" vibrators on the side of the hopper will further reduce arching, but the best answer is the use of pebble lime of size from ¼ inch to ¾ inch, provided suitable feeding and slaking equipment is available. Dust is reduced, arching in hopper is eliminated, and air-slaking of lime in storage is not as rapid with pebble lime as with the pulverized lime. Another physical property of interest is the color of the lime; white, gray, black, blue, etc. All are high in calcium oxide, and color is not a criterion of a good lime. The chemical properties and specifications are easy to determine in the laboratory. The lime should contain not less tran 90 per cent CaO, have a low magnesia, silica, and iron content, and be free of arsenic.

In many plants today, calcium hydroxide (hydrated lime) is preferred to calcium oxide, due largely to lack of information and equipment for slaking the oxide. The lime manufacturer is anxious to dispose of calcium hydroxide, since all fines from calcium oxide are converted into calcium hydroxide at the lime plant The water works executive must remember that he pays for slaking process plus freight on water in hauling hydrated lime in preference to burned lime.

Economic Considerations

TABLE I

	Typical Calcium Oxide Lime	Typical Calcium Hydroxide Lime
Insoluble Residue	1.57	.37
R_2O_3	.48	.52
Loss on Ignition	1.34	2.19
Magnesium oxide	1.26	.50
Calcium oxide	95.33	92.00*
CaO Equivalents	96.59	70.00
Cost Price Del./Ton	$11.00	$10.00
Cost Price per ton CaO	$11.38	$14.28

*Calcium Hydroxide—$Ca(OH)_2$ or $CaO + H_2O$.

In Table No. 1, a typical analysis and price of calcium hydroxide as compared to calcium oxide shows the economic status of the two types of lime. In buying a typical pebble calcium oxide in place of calcium hydroxide, a net saving of $2.90 per ton of CaO equivalents is realized, plus higher operating efficiency. In actual plant operation the saving will be greater, since the theoretical ratio of one part CaO to 1.32 parts $Ca(OH)_2$ approaches a practical operating ratio of 1 part CaO to 1.5 parts $Ca(OH)_2$.

Another way to save money in buying quicklime is in the size of the lime. A pulverized calcium oxide (passing 200 mesh) is more costly than a standard pebble or cracked lime. The manufacturer must charge for the expensive process of pulverizing and will raise the price of calcium oxide from $11.00/ton to approximately $13.00/ton for the pulverized product. Also for large plants, the lime shipped in 15 ton cars costs more than in 25 ton cars, due to the freight rates.

With the money that can be saved by shifting from calcium hydroxide to pebble calcium oxide, an excellent feeder and slaker can be purchased and the lime treatment will become a controlled process rather than the usual "hit or miss" process. The operator should investigate and experiment with different types of lime to find the one best suited to his own plant and local conditions.

Lime Slaking Equipment and Its Operation

The operation of the slaker is not easy. Like a man learning to ride a bicycle, the problem looks simple yet requires initial research and a few hard knocks before the art is mastered.

First, and most essential, is an efficient dry-feeder. In the Richmond Filter Plant, an Omega lime feeder delivers the lime to the slaking vat at an astoundingly accurate rate. The feeder is a gravimetric batch type having a maximum capacity of 175 pound/hour and a minimum capacity of 1.75-pound/hour. The feeder has a 1,000 pound capacity, and properly designed hopper equipped with an agitator and mounted on a sensitive beam scale. The adjusting mechanism for changing the rate of feed is located in a compact unit with an alarm to indicate any trouble in feeding, such as an empty hopper or failure of material to leave the hopper. The lime feed is controlled by the vibrating plate at the bottom of the hopper. The pebble lime of size not exceeding ¾ inch size falls off the vibrating plate directly into a compact Omega Slaker located on the same floor with the feeder in a floor space of only 54 inch by 84 inch for both feeder and slaker. The unit is equipped with a water operated vapor removal system to collect dust and steam from the slaker. The water from this unit is not wasted, but is used as make-up water for the slaker or in conveying the lime to the

point of application. The slaker has a minimum retention period of 30 minutes at the maximum rate of feed and is agitated with a motor driven impeller so adjusted to give proper circulation in the chamber.

Temperature Control Important

The optimum temperature for slaking will vary both with the type of lime and the retention period in the slaker. The most efficient slaker temperature range is between 150° F. and 180° F.; above 180° F. the steam and vapor will overload the vapor removal equipment and cause corrosion of the slaker and feeder. In the Richmond plant, the optimum temperature is 160° F. using a pebble lime having a 96 per cent CaO content. In order to maintain this temperature in the shaker, with our incoming water varying between 33° F. and 85° F., an electric water heater of three No. M-240, 4,000 watt Chronolox immersion heaters was purchased for the job. The heaters are equipped with three-way switches for seasonal control and thermostats on each unit to supply makeup water at a uniform temperature regardless of the temperature of the incoming water. The heat of hydration of calcium oxide is 273 calories per gram. However, in slaking small quantities of lime some of this heat is lost and must be supplemented by heat from the make-up water.

Proper Water Ratio

In slaking lime, too little water gives a heavy slurry that is too thick to be agitated properly by the impeller, yet an excess of water increases the expense of heating make-up water and will dilute the lime so that maximum retention time in the slaker is materially reduced. Different brands of lime require variable quantities of water, but a slurry of the proper viscosity is usually obtained by a ratio range of 1 pound lime to 3 pounds water to a ratio of 1:4½. After a series of experiments at the Richmond plant, the ratio of 1:4 was adopted and gives excellent operating results.

To control the ratio, a standard water meter is connected in the supply line to the heater. The meter was geared so that the lowest dial actually reads 3 times the amount of water passing through the meter. For example, one cubic foot of water passing through the meter indicated three cubic feet on the dial. This method was devised to afford the operator a chance to check the water flow at low rates much more readily than with the regular meter dial. After checking the flow, the operator refers to a chart (see Table 2) showing the meter reading corresponding to each rate of lime feed for a ratio of 1:4, adjustment being made by the needle control valve if necessary. Example: Feed 50 lbs./hr. of lime. Requires for ratio 1:4, 50 × 4 or 200 lbs./hr. of water equals

$$\frac{200}{62.4} = 3.2 \text{ cu. ft. per hour of water.}$$

On special dial, this reads 3.2 × 3 or 9.6. On the chart opposite the rate of 50 lbs./hr. is the value 9.6 which should be the reading of the meter for one hour. The operator adjusts the valve to get this reading.

TABLE II

Water Meter Reading vs. Dial Setting for Optimum Ratio one lime to four water.

Pounds/hr. Lime	Dial Setting	Meter Reading (Cu. ft.*)
1.75	1	.3
8.75	5	1 6
17.50	10	3.4
26.25	15	5.0
35.00	20	6.7
43.75	25	8.4
52.50	30	10.0
61.25	35	11 7
70.00	40	13.5
78.75	45	15.1
87.50	50	16.7
96.25	55	18.4

*Special Meter Dial. Indicates three times actual flow.

The lime after slaking is diluted with water from the vapor removal unit and flows over a weir into the outlet line. Some lime has considerable core so that the machine is designed for core removal, without stopping the slaker operation. The core is removed to a chamber to be washed to recover any calcium hydroxide on the surface and is then dumped into a trash can under the slaker. Tests are being run on the amount of unslaked lime in the sample collected at the effluent of the slaker but are not complete enough at present to report in this paper.

Piping Lime Suspensions

No other problem seems more perplexing than that of transporting the lime to the point of application 300 feet or 400 feet from the slaker. If duplicate lines are available, one line can be cleaned with a chlorine solution while the other line is in service. However, caution must be observed to prevent the chlorine from actually attacking the iron pipe. Recently suggested is the use of "Calgon" to keep the lines free of incrustants but so far little work has been reported on this method. Many plants use rubber hose and clean the line by beating or shaking the hose. The author has found that the open trough is the simplest method of delivering the lime, provided the necessary fall between the machine and point of application can be obtained.

pH Control Simplified

So accurate is the control of pH with the new Omega slaker that in the Richmond plant we can hold a constant pH of 8.7 in our finished water. It is important to note in Table No. 3 that prior to the installation of the slaker, we had trouble in our distribution system with a decided drop in pH. Now with the present slaker we have only a slight drop and a corresponding decrease of iron in the dead-ends. We can only explain this by the fact that the controlled slaking is productive of a more highly peptized lime suspension—more nearly a colloidal suspension.

TABLE III

Station No. 34*
Location—Broad Rock Road

	Before Slaker Installation 1938	After Slaker Installation 1940
Res. Cl_2	.00	.00
Turb.	6.0	.80
Color	40	10
Alk. (M)	23	36
Alk. (Phen.)	0	4.5
CO_2	0	0
pH	8.1	8.6
Fe_2O_3	4.0	.40

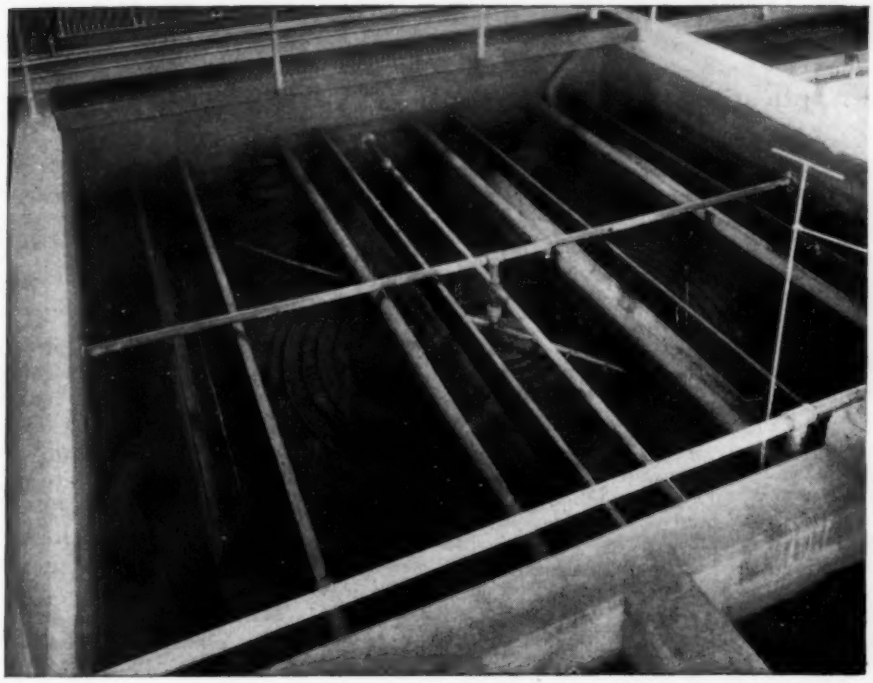
*This station is located near a dead-end.

It is hoped that water works men will study lime treatment and get more lime per dollar. Remember that often obsolete equipment can be scrapped and new equipment purchased with the saving. so why not have a modern plant at no extra cost?

STUART-BRUMLEY CORP.

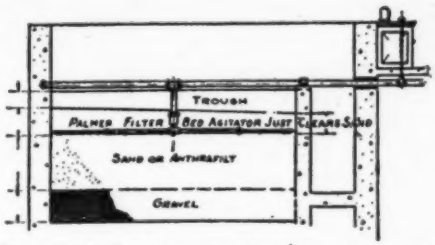
516 N. Charles St. BALTIMORE, MD.

PALMER FILTER BED AGITATORS



Advantages

- Long filter runs.
- Less wash water required — averaging 40 per cent reduction.
- Complete elimination of mud balls.
- Reduction of chlorine demand in filtered water—because of removal of organic matter in the filter sand.
- No more cracking or shrinking of the beds.
- Sand is as clean as new sand after about three weeks operation of the agitators.
- Better tasting water.



Operates by water at city pressure. High velocity, low volume jet action completely scours the expanded filter medium. Low cost.

Installations

Cities

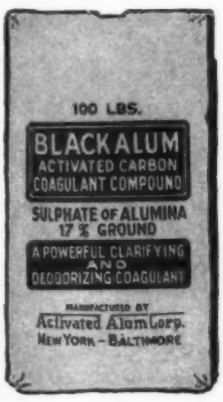
Hundreds of municipalities have Palmer Filter Bed Agitators.

Industrial Companies, such as

Anheuser Busch, Inc.
E. I. du Pont de Nemours and Co.—8 plants.
General Electric Company.
Hammermill Paper Co.
New Bedford Rayon Co.
American Enka Co.
Gulf States Utilities Co.
Rayonier, Inc.—3 plants.

CORROSION RESISTING PAINTS – FILTER SAND
FILTER ALUMS – POWDERED ACTIVATED CARBON – BLEACHING CLAY

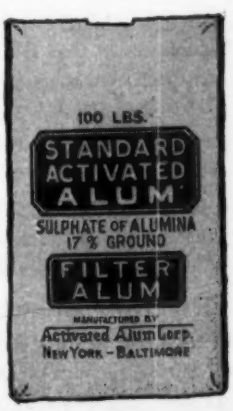
Dustless Blackalum



A powerful deodorizing and decolorizing coagulant. Contains powdered activated carbon. Prevents fermentation of sludge in basins. Fast Floccing over a wide pH range. Particularly effective for summer coagulation. Removes tastes from water supplies.

Standard Activated Alum

An economical, high alumina content coagulant. Compounded for use when dealing with water which is difficult to handle. One of America's largest selling coagulants, providing maximum coagulation economy with greatest efficiency.



THE ANTHRACITE EQUIPMENT CORP.

101 Park Avenue
NEW YORK CITY, N. Y.

H. G. Turner—Research Engineer—State College, Pa.

ANTHRAFILT — an Improved Filter Medium

Anthafilt and Its Application

Anthrafilt is made from a **selected** Pensylvania anthracite which has been cleaned so as to have a minimum ash. This cleaned anthracite is then screened and classified hydraulically to yield sizes suitable for filter purposes.

Anthrafilt is used as a mechanical aggregate in place of sand and gravel in all kinds of filters, i.e.

Rapid gravity filters	Slow filters
Swimming pool filters	Pressure filters
Hot process softening filters	Oil removal filters
Cold process softening filters	Alkali filters
Mechanical sewage filters	Acid filters
Revolving screen filters	Sewage sludge-beds
Portable filters	Household filters

The entire filter bed may be made up of Anthrafilt of various sizes or only the top layer may be of Anthrafilt over the usual bed of gravel.

Advantages of Anthrafilt

High Filtration Rate: Rates up to 200 mgad are obtainable with Anthrafilt without sacrifice of effluent quality. The accepted average rate with sand is 125 mgad.

Long Filter Runs: The larger, irregular Anthrafilt grains allow less clogging with algae or other fibrous substances. The angular grain surfaces provide greater entrapping areas for the removal of turbidity and bacteria. The differences in shape and specific gravity of the grains, by decreasing classification after back washing, allow the whole depth of the filter bed to be active in the filter operation.

Low Wash Water Costs: The long filter runs and consequent less frequent washing and the low degree of packing after back washing combine to cut the usual wash water requirements at least in half.

No Cementing with Lime, Manganese or Iron: Lime will coat on Anthrafilt but this coating readily flakes off without any cementing action if filters are properly operated. Manganese and iron salts precipitated on Anthrafilt by the lime treatment are easily removed by back washing.

High Degree of Expansion: 50% expansion is obtained with half the back wash velocity required for sand.

Coarse Sizes Can Be Used: The irregular shape and natural filtration characteristics permit the use of much larger sizes with equal results.

Gravel Beds Stay Flat: No ridging or mounding and less cracking and pulling away from side walls during operation.

Low First Cost: Lighter weight per unit volume balances the cost differential between Anthracite and sand and saves on freight and handling charges.

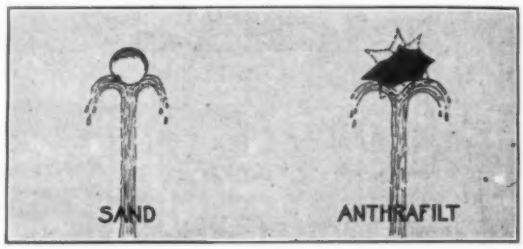
Filtration Characteristics

Anthracite granules are irregular shaped and of varying densities. Weights run about 53 pounds per cubic foot as against 100 pounds for sand. The irregular shapes provide greater porosity resulting in more rapid filtration with no loss in character of effluent and with considerably less loss of head.

The variable densities of Anthrafilt particles cause less classification after back washing and the lighter, irregular shapes allow easier expansion and more effective cleaning.

The greater bulk of Anthrafilt requires less tonnage per filter bed. Attrition losses amount to less than 0.25% per year.

Anthrafilt successfully removes lime, iron and manganese salts and will not form a permanent coating under proper conditions of treatment and filter operation. Lime flakes off easily without cementing and the iron and manganese salts are readily removed by back washing. Oil is easily removed from boiler water after coagulation with ferric sulphate, ferrous sulphate or alum. Anthrafilt can also be used for the filtration of acetic and sulphuric acids and caustic soda solutions. Being insoluble in alkaline waters, Anthrafilt produces silica-free water in hot process water softening.



Upward impulse of water produces greater agitation of angular grains, hence Anthrafilt beds are cleaned more effectively.

Anthrafilt No. 1 is usually made in sizes ranging from effective size of .60 m.m. to .80 m.m. the uniformity coefficient is less than 1.75 in all cases. We can make smaller sizes or larger sizes, but for special cases only. The remaining sizes of Anthrafilt are as follows:

No. 2. Anthrafilt—3/32" x 3/16"
No. 3. Anthrafilt—3/16" x 5/16"
No. 4. Anthrafilt—5/16" x 9/16"
No. 5. Anthrafilt—9/16" x 13/16"
No. 6. Anthrafilt—13/16" x 1-5/8"
No. 7. Anthrafilt—1-5/8" x 2-7/16"
The above sizes have 20% tolerance.

ANTHRAFILT ECONOMY

When Used in Existing Filtration Plants

Increased capacity with same plant
Decreased volume of wash water
Lower maintenance cost through elimination of ridging, mounding and air binding.

When Used in New Filtration Plants

Lower plant investment
Lower cost per cubic yard
Lower wash water costs
Lower maintenance costs

FILTER BED MAINTENANCE

A Year's Experience With the Palmer Filter-Bed Agitator

By E. C. GOEHRING, Chemical Engineer

Beaver Valley Water Co., Beaver Falls, Penna.

THE proper maintenance of the sand beds in filters is a problem that is found in most filter plants, and satisfactorily solved in but few. Mudballs, sand coatings, bed shrinkage from side walls, surface cracks and hard spots in the lower bed are evils that practically all operators have to cope with at one time or another.

Many remedies have been proposed in recent years for correcting or minimizing these troubles, but none in the writer's opinion have produced such results as have been obtained by the installation of the recently perfected Palmer "Filter Sweep." This device not only clears up these troubles, but also maintains the beds in as perfect condition as one might wish for. If this statement appears to be a "plug" for the "Filter Sweep" let it be so. The results justify as much.

The Eastvale plant of the Beaver Valley Water Company has six units of one million gallon capacity each, and of rather an unorthodox shape; namely, 25½ by 14 feet. When this plant was designed, in 1922, a wash water rise of 12 to 15 inches was considered adequate. Two reinforced concrete wash water troughs running lengthwise, having a total cross-section area of two square feet, were provided to carry off the wash water coming from a 50,000 gallon tank providing a maximum head of 11 pounds static pressure.

Some Operating Experiences

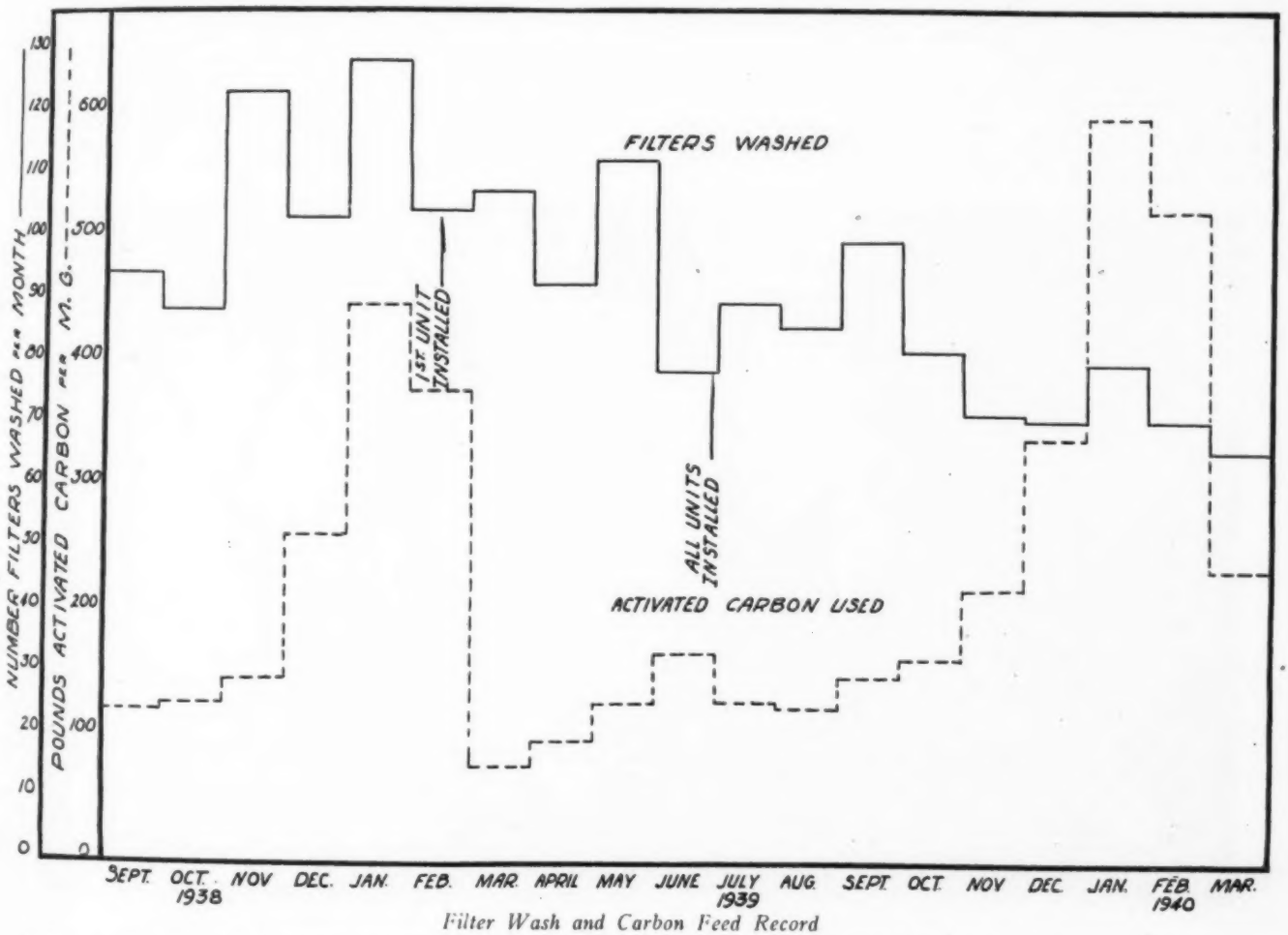
After several years operation, it was found increasingly more difficult to maintain the sand beds in the proper condition, and considerable maintenance had to be used to remove hard spots, to prevent cracks, and sidewall shrinkage. This required passing the sand through a jet washer at least once each year, and thereafter intermittent shoveling and hosing with high pressure nozzles between the scouring jet washes.

In 1936, when higher wash rates and increased sand expansion were being advocated as effective means of sand bed conditioning, a larger wash water tank was installed at a higher elevation to give higher rates of wash. Rates of vertical rise as high as 40 inches per minute were available with the new tank, which has a capacity of 70,000 gallons. While these higher rates helped to keep the hard spots smaller, flooding of the small capacity troughs made our higher rates relatively ineffective.

The Beaver River, which is our source of supply, fluctuates widely in its characteristics, especially in color, taste, and odor. Increased use of activated carbon has been necessary to minimize these tastes and odors. During the past two years abnormally high dosages, ranging to well over 1000 pounds per million gallons, have been required at times.

The increased use of carbon has resulted in increasing the problem of keeping the filters in good condition, and required more frequent washing to prevent passage of the carbon to the clearwell.

The graph, showing the average carbon dosage in pounds per million gallons, indicates clearly the effect on the number of filters washed, particularly before the installation of the Palmer "Filter Sweeps." To anyone who uses carbon, it need not be


NUMBER FILTERS WASHED PER MONTH
POUNDS ACTIVATED CARBON PER M. G.
FILTERS WASHED
1ST UNIT INSTALLED
ALL UNITS INSTALLED
ACTIVATED CARBON USED
SEPT. OCT. NOV DEC. JAN. FEB. MAR. APRIL MAY JUNE JULY AUG. SEPT. OCT. NOV DEC. JAN. FEB. MAR.
1938
1939
1940

Filter Wash and Carbon Feed Record

Indicating the effect of the "Filter Sweep" in producing cleaner beds and lengthened hours of filter service between washes. More impressive is the record in the face of heavier carbon loadings since the "Sweeps" were installed.

said that the filter mat becomes unusually sticky and most difficult to remove.

During periods of high colored raw water, coagulation on the acid side is required, and lime is withheld for addition just ahead of the filters for pH adjustment. The combination of high carbon dosages and lime on the filters brought about the appearance of large numbers of black hard balls, which were light enough to remain in the upper six-inch sand strata. Attempts to wash them out by ordinary means failed, and only screening effectively removed them.

Some Filters Overhauled and Experimental "Sweep" Installed in Another

In November and December, 1938, two units (Nos. 1 and 2) were completely overhauled and the sand and gravel replaced with new media. A program was set up, at that time, to replace the beds in all of the units.

In January, 1939, the opportunity presented itself to install one of the new Palmer "Filter Sweeps." This demonstration unit was installed in No. 6, which was the next unit scheduled for replacement.

After about two months' use of this rotary jet sand bed agitator, it was noted that the filter improved to the extent that former hard spots were removed and small surface cracks no longer showed up. The sand began to lose its "sticky feel" and became brighter in color. At the same time, it was noted that No. 1 and 2 units, with the new sand, were becoming infested with "raisin-like" spongy balls of carbon and lime, along with alum floc and algae. The apparent benefit that No. 6 was receiving from the agitator prompted us to install Palmer's "Sweeps" in all of the units. This work was completed in June, 1939.

During the experimentation with the first unit, it was found that better washing could be obtained by increasing the carrying capacity of the wash troughs. We bolted steel plates to the outsides of the concrete troughs, which increased the free-board 6 inches and increased the effective cross-section area of the troughs from a total of 288 square inches to 508 square inches. This increase made it possible to use wash water rises up to 20 inches without flooding the troughs.

It was also noted that a sand expansion of from 10% to 15% was sufficient to make the washing effective when using the "Sweeps," whereas, before, expansion as high as 40% to 50% did nothing more than allow the balls to bob up and down more and to settle deeper in the sand itself.

An almost immediate improvement was noted upon the complete installation of agitators in all units, especially in the new sand units (Nos. 1 and 2), which became entirely cleared of the "raisin-like" balls in a short time. Moreover, these filters have remained as clear as the day the sand was installed over sixteen months ago.

In the four filters with the old sand, the results have also been remarkable in that the former sticky and surface crack conditions have been removed. The sand now is clean and bright. Further replacement with new sand has been indefinitely postponed, resulting in a considerable saving in labor and material cost. Periodic inspections indicate that the beds and the sand are continually improving.

Wash Water Economy

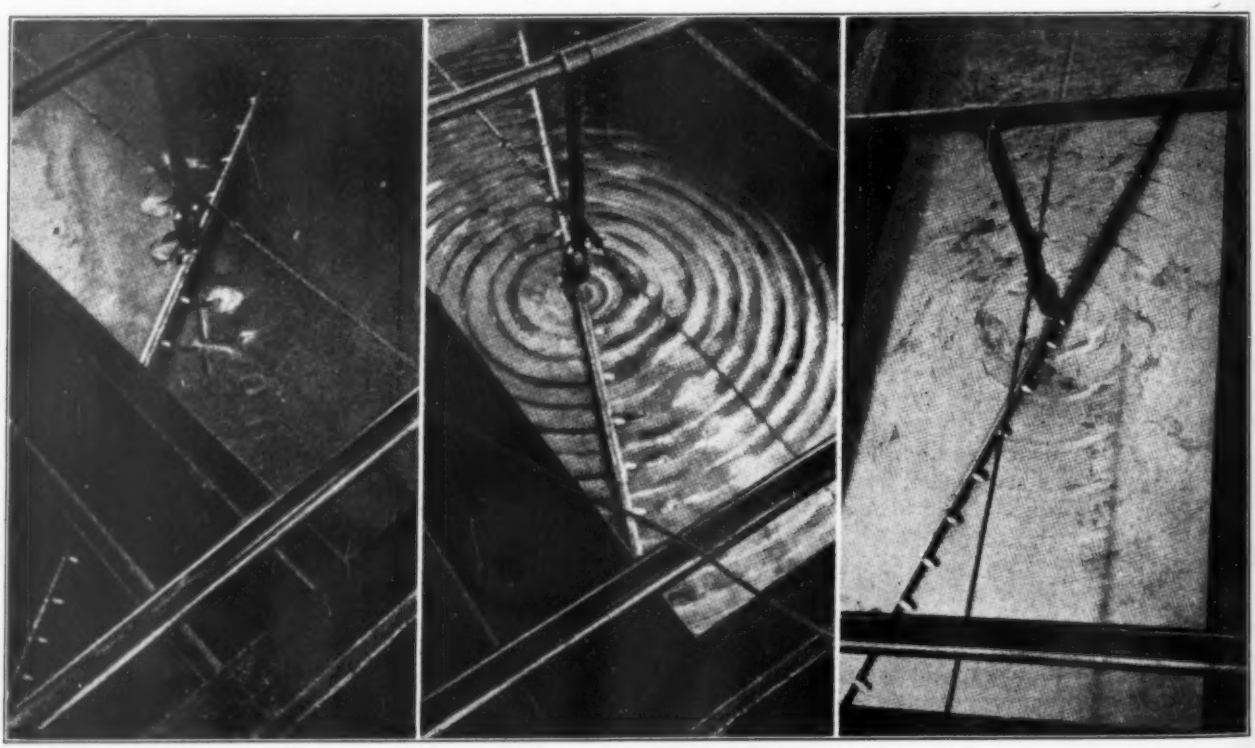
During the past year's experience with the Palmer "Sweeps," no attempt has been made to economize on the amount of water used per filter wash. However, a considerable economy has been effected in that the number of filters washed per month has dropped considerably. The accompanying graph indicates the drop in numbers of filters washed very effectively, in spite of the fact that carbon dosages have been increasingly higher than during a like period prior to the installation of the agitators. The decrease in the number of filters washed is indicative of the increased lengths of runs between washings resulting in a saving in wash water in addition to other advantages from longer filter runs.

A typical example may be cited on the graph. Comparing January, 1939, with January, 1940, indicates a 38% reduction in number of filters washed. This, in spite of increased carbon dosages of 444 pounds per million gallons in January, 1939, to 593 pounds per million gallons in January, 1940.

We have every reason to believe that, inasmuch as this past year has shown a considerable reduction in wash water, the reduction should be increasingly more, in the future, as the past year has been the cleaning period during which the beds have been continuously improving.

The "Filter Sweep"

The pictures of the "Sweep" indicate the nature of the device, which is substantially like the old mechanical rakes, except that instead of wooden or steel teeth, jets of water do a better stirring job. The jets are set in a horizontal arm which revolves like the conventional lawn spray, or the revolving distributor on modern sewage filters only at a much more rapid rate. The nozzle pressure is about 50 pounds per square inch, and, even



The Palmer Filter Bed Agitator and Bed Condition

(1) *Dirty filter drawn down before starting agitator;* (2) *Showing grooves cut by agitator jets;* (3) *After the wash with agitator and up-flow wash, producing only* 10 *to* 15% *bed expansion, and* 3 *to* 4 *minute operation of the agitator.*

with the sand bed not expanded, the jets penetrate as much as four inches into the sand. The pictures show the effectiveness with which the area of the bed is covered by the jets; but only one of the two revolving arms with which each filter is supplied is shown. It is particularly significant to find that the corners of the filters, as well as other segments not directly under the revolving arms, are effectively agitated by jets in the ends of the arms. Our experience has been that the corners on the new sand units are as clean as the remainder of the bed.

Determining Most Effective Use

The operation of the agitators, in conjunction with the usual washing procedure, was modified from time to time to arrive at the procedure which gave the best results.

When a unit is ready to be washed, the filter is drawn down until the water level is even with the jets. The agitator water supply valve is then opened and the agitator made to revolve for one minute. This breaks up the surface mat and makes a heavy slurry of the material usually found on and near the bed surface. This operation has proved a very important part of the procedure. The wash water valve is then opened to give the necessary volume to *just fill* the troughs. The agitator is allowed to rotate for from three to four minutes during the up flow (bottom) washing period before the high pressure supply to the "Sweep" is shut off. We have found that with not more than 10% to 15% expansion, the agitators are completely covered with sand and the jets penetrate into the lower sand layers. Washing is continued until the filter is as clean as experience indicates is consistent with practice for best initial filtration efficiency.

In some cases, especially when the agitators were first installed, it was found almost impossible to "clear up" the filter as long as the agitators were in operation. This definitely indicated the freeing of foreign matter not ordinarily removed in the usual washing procedure. Now, since the filters have become more truly clean, the beds can be washed to a "clear-up" point (meaning clarity of wash-water leaving) with the agitators in operation during the entire washing period. The major objection to this procedure is that when the agitators are shut off *after* the bottom wash-water, upon drawing the filter down, it will be found that the sand will be in a saucer-shaped contour instead of perfectly flat. The writer has observed as much as a six-inch difference of elevation between the sides and the center of the filter bed, enough to stop the agitators when the wash water was shut off before the agitators. This indicates that during the agitation period a very pronounced sand recirculation from the side walls and corners to the center must be taking place in the bed; a feature which commends this device over stationary surface wash jets.

Summary

The past year's experience with this form of surface agitation device indicates to the writer that such troubles, as mudballs, surface cracks, bed shrinkage, hard spots, and sand coatings removable by abrasion, can be effectively removed and the beds maintained in good condition. A definite economy in the use of wash water can be expected after the beds have been cleaned.

The writer's experience with the Palmer "Filter-Sweep" prompted him also to recommend the installation of four units in the Shenango Valley Water Company's filtration plant at Sharon, Pennsylvania, where they are now operating with complete satisfaction also.

DEVICE FOR FEEDING LIME SOLUTION INTO MAINS

By E. T. CRANCH
Manager, New Rochelle Water Co.
New Rochelle, N. Y.

THE New Rochelle Water Company purchases its water from the Croton System of New York City. This is an impounded supply with a normal pH ranging from 6.8 to 7.2.

In order to absorb the free CO_2 and thus reduce the corrosive character of the water The New Rochelle Water Company treats all the water it takes from the Croton Aqueduct with lime to maintain a pH of 8.6. The water is lifted from the Croton Aqueduce by means of pumps located about 15 feet above the water level in the aqueduct. A saturated solution of lime water is continuously fed into the suction line. It was found that lime would build up in the feed piping. By closing the corporation cock all the piping could be easily cleaned except the corporation cock itself, which became badly plugged and it was almost impossible to clean it without shutting down the pumps and losing the suction. As it takes about an hour to prime the suction header after the suction has been lost the station operators never liked to work on the corporation cock.

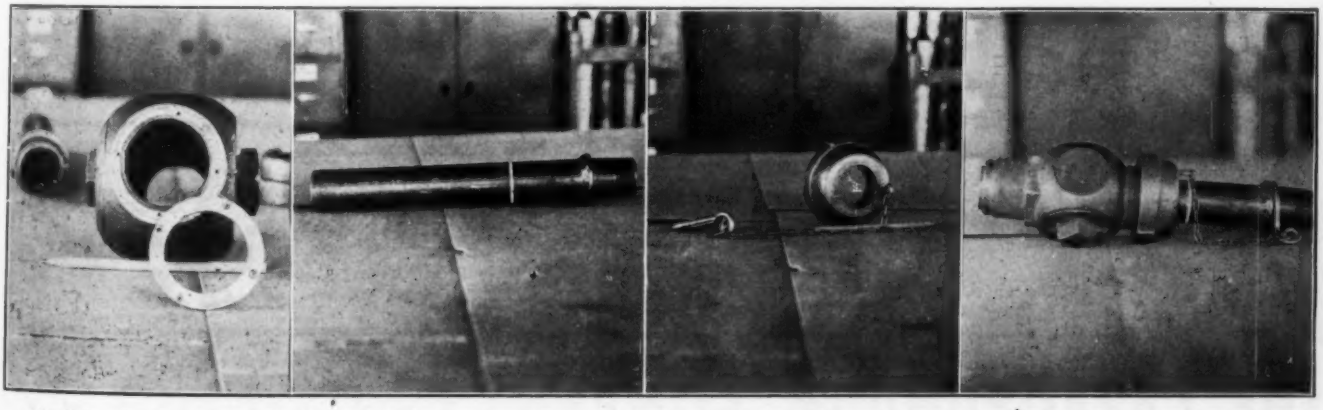
Then it was suggested that a connection to the suction line be made up similar to the usual type of device for feeding chlorine solution. Accordingly Mr. Charles Neydl, who has charge of the Meter Repair Shop, made the device illustrated.

Method of Installation

The device has a tube which slides through a gland and corporation cock and projects into the main. It can easily be withdrawn under pressure, or suction, cleaned and returned.

In order to insert this unit it was necessary to remove the old 1½ inch corporation-cock, drill out the old hole in the 30-inch cast iron suction line to fit a 2-inch corporation-cock and insert the new 2-inch cock. All this was done with a regular Mueller tapping-machine, with the loss of very little suction.

After the tapping machine was carefully centered over the existing 1½-inch corporation-cock the pumps were shut down and the vacuum priming device started. The 1½-inch cock was then removed by use of an extracting plug. Of course the check valve in the tapping machine did not hold against a negative pressure, but this was overcome by placing a board across the open end of the barrel of the tapping machine as soon as the top was removed. In this way so little suction was lost that the priming device had the pumps ready to start again by the time the insertion of the 2-inch corporation-cock was completed.



(1) 2-in. Corporation cock fitted with stuffing-box plate exactly to fit 1½-in. Wrought Iron pipe. (2) 1½-in. Wrought Iron pipe with ring welded on it for stop-chain. White painted band indicates correct amount of insertion when feeding lime. (3) 2½-in. Cap drilled exactly to fit 1½-in. Wrought Iron pipe and equipped with rings and stop-chain. (4) Assembled Unit.

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ALOXITE BRAND POROUS UNDERDRAIN SYSTEMS

For Rapid Water Filtration

Filter with plain plates forming a false bottom

Filter with channeled plates

1. *Elimination of filter bottom troubles . . . protection against loss or upset of filter media . . . no corrosion.*
2. *Longer filter runs . . . uniform back wash.*
3. *Lower pumping costs . . . reduced heads.*
4. *Lower cost of construction.*

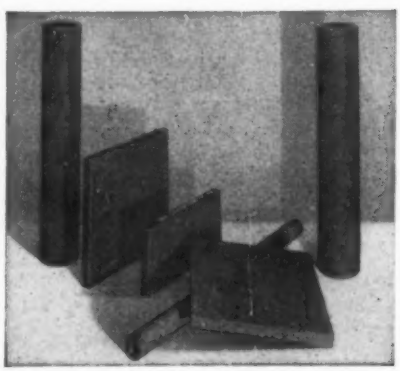
Now being proved in more than 100 separate installations throughout the world

THESE benefits are realized through the inherent simplicity of design of the Aloxite Brand Porous Underdrain Systems which result in the *complete elimination of graded gravel* and the reduction of all vertical dimensions. Our sanitary engineers will gladly furnish consulting engineers, plant superintendents and others who are interested with further details. Write direct to the Niagara Falls office.

ALOXITE BRAND DIFFUSER PLATES AND TUBES

For Sewage and Water Aeration

1. Activated Sludge.
2. Sedimentation Pre-aeration—Grease Separation.
3. Trickling Filter Pre-aeration.
4. Post Aeration.
5. Grit Washing.
6. Sludge Mixing.
7. Channel Aeration.
8. Chemical Treatment—Pre-aeration and Mixing.
9. Chemical Flocculation.
10. Sludge Elutriation.
11. Water Aeration and Chemical Mixing.
12. Water Carbonation.



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PRACTICAL ASPECTS OF POROUS PLATE FILTER BOTTOMS

Based on Experiences at Larchmont, N. Y.

By HENRY T. HOTCHKISS, Supervising Chemist
Department of Water and Sewage, Larchmont, New York

IT IS obvious that in passing down through a filter bed, water goes from zone to zone of varying function. The sand-gravel interface has received notice in connection with both sand support and wash water distribution. Such functional analysis is necessary in order to understand the losses of effectiveness which may arise from disruption in any of these zones and so that corrective measures may be taken.

In an otherwise quite excellent outline[1] there is found a general disclaimer for faulty filter design in the following statement: *"Sometimes trouble occurs in a filter bed due to local displacement of gravel. It may be that some of the large gravel has been forced upward through the fine gravel, or the fine gravel may be ridged or mounded in places. Unless the causes for such conditions are understood, the general movement may be wrongly attributed to faulty design or construction of the filter bottom."*

This, the writer believes, should not be accepted as a dogmatic statement that filter design has been perfected or standardized, but rather as an admission that improvements are needed.

Again a statement[2] is made that *"Another drawback is that although we may say filters are poorly designed, we do not have good proof of the assertion.*

"Perhaps most of us believe we know a better filter design, yet no one has produced a filter bottom in which filter beds handling various types of water have all remained in good condition. Either the ideal design has not been found or there are certain inherent weaknesses which cannot be remedied by any design of the bottom. The latter is believed to be the reason."

This statement should spur on investigations seeking to perfect both design and operation.

Bed Surface the "Tell-Tale"

The surface layer gives some indication of the state of affairs in the zones below. Mounds and craters are generally symptoms of internal troubles. Smaller mudballs may be localized at or near the surface, but hard spots and cracks due to bed shrinkage result from dirty sand or upset gravel. Surface washing systems, when provided, give the operator a valuable tool for improving sand conditions. They cannot, however, be expected to correct deep bed disruptions. A clever operator, even without use of surface wash, can, by the use of rake and water jet, "iron out" these surface blemishes. This, however, does not correct the underlying flaws. These can only be cured by a major operation.

There is, unfortunately, no influence acting during the backwashing operation to restore, once disturbed gravel to its original graded position. This is so because those forces which move the gravel are all localized and due to high velocities created by various conditions over which the operator may or may not have control. Studies indicate that at times, when wash water is first introduced—and even when the rate-of-rise is still low—there is a tendency for the sand to expand *from the bottom* as the sand mass is lifted. Then a weakening takes place, at one or more points. Finally gravity prevails and the less dense fluid (sand-water mixture) gushes up through. The velocities of these vertical jets, coming from deep down, are of gravel moving magnitude. This may and does happen before a normal maximum rate-of-wash is reached. The fewer the points of breakthrough, the more violent is the local action. [Filter beds containing air removed from the water during filtration have been known to "blow-up' when cracking the wash valve with the net result of an inverted gravel bed and trouble.—Ed.]

In recent years, the importance of the sand-gravel junction has been more fully appreciated.[3] In this zone the wash water is finally distributed to the sand. The loss-of-head throughout the interface must be of constant magnitude if even velocity distribution is to be attained. Here, however, is the most unstable portion of the gravel, because the gravel approaches sand grain dimensions.

Why the Gravel Bed?

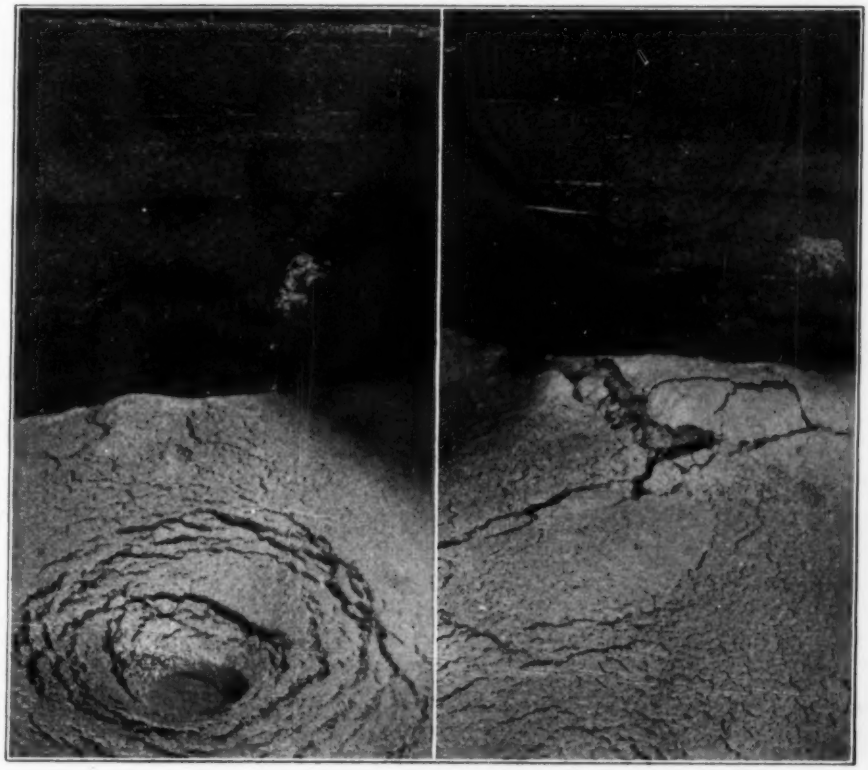
Sand of good quality and proper size is provided to act as a straining medium, primarily for removing the suspended matter present in the applied water. In rapid mechanical sand filters the action is physical in nature.

As for the gravel, it does not seem possible to build such a substantial case of necessity. As a matter of fact, from what has been outlined previously, the evidence indicates that a good case exists for eliminating gravel from filter design. This can be done if a method of supporting the sand and distributing the wash water can be provided. The proposals of H. N. Jenks[4] and especially the studies of Professor T. R. Camp have led to the production of manufactured porous plates for this purpose. Their use appears to be a cure for chronic filter illness due to deep bed gravel upheavals.

The Porous Plate Bottom

Any discussion of the merits of porous plates over conventional under-drain systems has been purposely omitted since this topic has already been given some attention.[5]

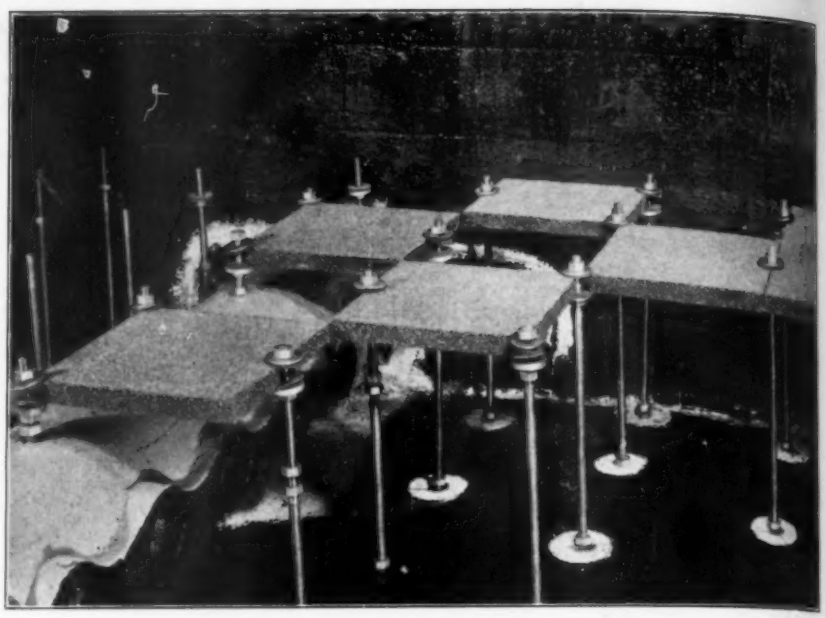
It must be admitted that there is the likelihood of fine grained



Some Cause for Concern
Filter Bed Conditions at Larchmont Which Aroused Our Interest in the Possibilities of Improved Design and Eventually the Installation of Porous Plate False Bottoms and Elimination of Trouble-making Gravel.

plate clogging; but because of the comparatively low initial head loss through the plates and because of the equalizing factor which exists as the less resistant pores become constricted, considerable leeway is provided before cleaning operations are required. Possibly, routine treatment of the plates with dilute acid at one or two year intervals will be found desirable. Certainly, the characteristics of the applied water should be scrutinized carefully if calcium carbonate or other deposition is probable, so that suitable provisions may be made for protecting the plates.

Since the advent of the porous plate filter bottom there has been a conservative desire to know, in advance, just what the life of the plates will be. There is no question concerning their mechanical strength. Nor is there doubt of their ability to withstand the chemicals normally present in water and sewage, or even acid solutions of considerable strength. The question raised is a matter of performance. Will clogging take place at a rate which will nullify their usefulness? Subsequqent to the provision of automatic rate-of-wash control it has been possible to secure comparative loss-of-head data.



Construction of Porous Plate Filter Bottoms at Larchmont, N. Y.
The Norton plates (12"x12") are installed with three point support, making for ease in levelling and alignment. The rods, washers and bolts are of "Everdur" bronze. The plates form a false bottom above the original manifold.

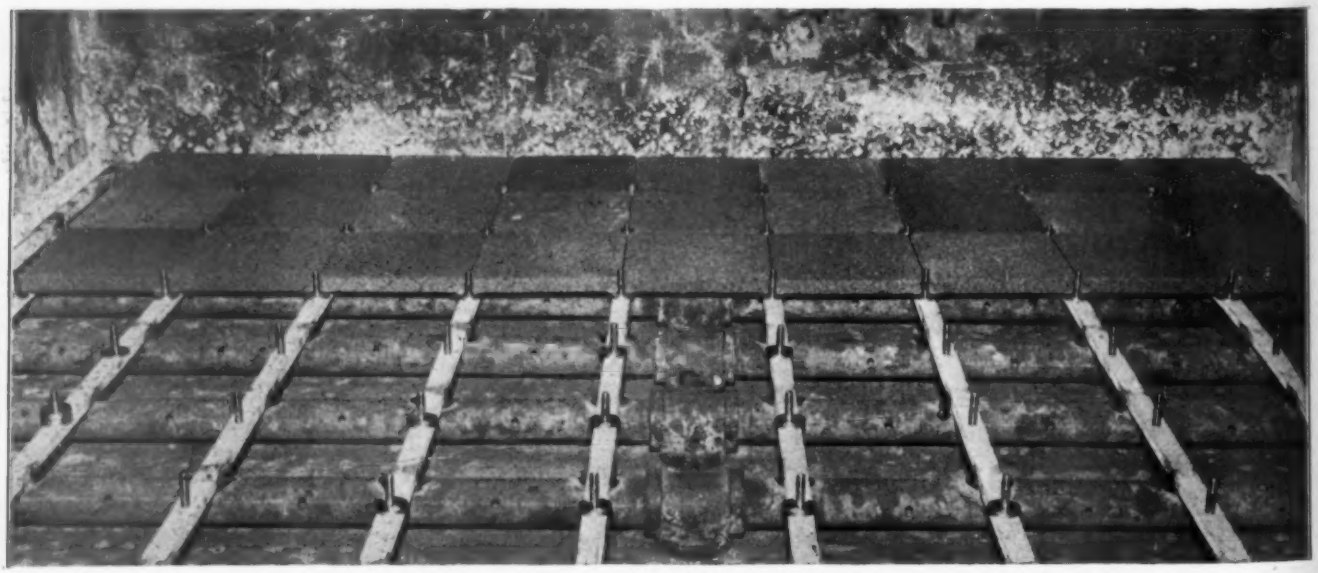
Larchmont Experiences

The original filter unit, equipped with a porous plate bottom and placed in service July, 1939, in our plant, as recounted in this magazine,* has been in continuous use. This was equipped with piezometer tubes just above and below the plates in order to follow any changes in the hydraulic characteristics of the plates. Readings taken indicate, as anticipated, an increase in loss-of-head. An intermediate interval was also observed when the loss decreased for a time. The net result by February 21, 1941, was a total head loss through the plates of 24 inches of water. This was with a wash rate of 16.1 gals. per sq. ft. per min. (approx. 26 inch rise per min.). This head loss is not considered high. New plates showed an initial loss of four inches of water under similar condition. The loss during filtering at design ratings continues very low.

In order to provide some indication of the effectiveness of rinsing the plates with dilute acid, the unit was cut out of service on February 21st. The following procedure was used to introduce sulfuric acid, using fittings provided for the purpose in the original installation.

A syphon line, of common garden hose, was led from a crock on the filter gallery floor to the underdrain manifold. Water flowed into the crock and to the filter bottom by way of the syphon at about five gallons per min. The 66° Be. technical sulfuric acid was run into the crock at a slow rate by means of a glass funnel so that within an hour's time 81 lbs. had been used. A solution of 1¼ per cent by weight, on the basis of the acid used, was thus made and provided about 300 gals. of dilute acid. The level of water in the filter, which had previously been drawn down just to the sand, rose slowly. The water flowing through the hose was permitted to force the acid slowly up through the plates and sand for an hour.

Thereafter, wash water was introduced at a slow rate for an additional half-hour, when the water level had reached to within a foot of the lip of the wash gutters. Then the wash was continued at normal rate, utilizing 30,000 gals. to sweep out the residual acid and loosened solid. Water was then filtered to waste until the pH had increased to the point where the filtrate had become alkaline to methyl orange. The loss-of-head through the plates was measured during the wash. It was found that this mild treatment, over a period of two and one-half hours only,



Construction of Power Plate Bottoms of the Ford Motor Co.'s Plant at Flat Rock, Mich.
The "Aloxite" 12"x12" plates, resting on steel bars welded to the old laterals drilled along their sides, are held in place with studs, nuts and washers of phosphor-bronze.

had reduced the loss of head during the 26 inch wash rate to 12 inches of water, or *just one-half*. The cost was about five dollars.

An Air-Water Brush

The following interesting disclosure may possibly be premature, but we shall take the chance in relating it at this time. For some time since the initial plate installation in 1939, there has been the temptation to utilize the porous plate botom as an air diffusing medium in order to obtain the scrubbing air-wash effect, particularly since the merits of this form of agitation have not been seriously discredited. It happened that the installation of rate-of-wash control in conjunction with a new steel all-welded wash water tank made it possible to introduce air along with the wash-water; and, moreover, without any cost for equipment or power. This was done by applying the aspirator principle.

A tap was inserted in the upper leg of a 12-inch tee having a 10-inch side connection to the rate-of-wash controller set between the tee and the wash water storage tank. The upper leg is normally valved off, being connected to the tank to by-pass the controller if need be at any time. The lower leg is joined to the 12-inch wash water line leading to the filters. The center line of the tee stands about 13 feet above the sand surface. By cracking the valve at the tap as the wash valve opens, adequate volumes of air are inspirated and carried by the wash water to the plates. In this way very good air distribution is secured over about two-thirds of the area of the bottom. Varying degrees of violence of sand agitation and circulation, depending upon the volume of air admitted, have been secured. By shutting down the air before the end of the wash, as is usual, the air is swept from the system by the finishing water wash.

Thus the entire sand mass may be subjected to a thorough going-over without auxiliary equipment. This novel water-air wash procedure is possible with the rigid sand supporting medium, and absence of gravel.

Adequate descriptions of porous plate installations have already appeared.[6] Certain refinements of detail and construction features which have been incorporated in the three new units provided at the Larchmont, N. Y., plant are being covered in an article to appear in "Public Works."

When the water level is drawn down below the sand in the three new units, the sand surface is almost carpet smooth. The accompanying picture, in which a fairly heavy blanket of alum floc and activated carbon has been retained on the sand, is hardly a substitute for visual inspection. From an operating angle the results with the first bottom of porous plates have been very gratifying.

References

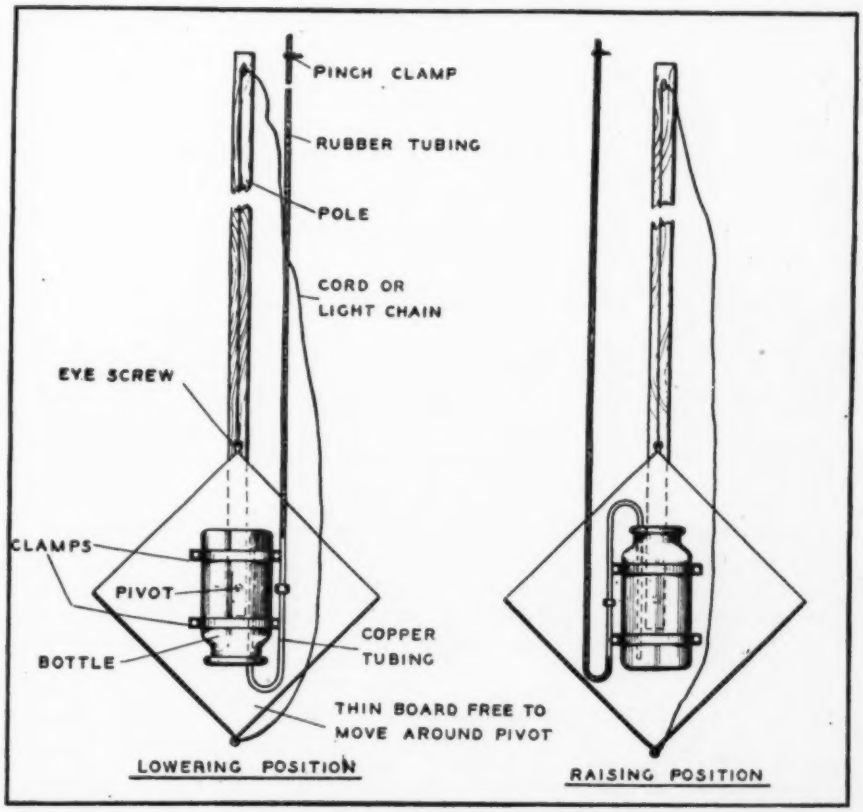
[1]Manual Eng. Practice No. 19 Am. Soc. C. E. (1940).
[2]J. R. Baylis, Water Wks. Eng. **93**, 1432 (1940).
[3]T. R. Camp, J. New England Water Wks. Assn. **49**, 1 (1935).
[4]J. Am. Water Wks. Assn. **16**, 542 (1926).
[5]H. T. Hotchkiss, Water Wks. & Sewerage **86**, 442 (1939).
[6]H. T. Hotchkiss, Water Wks. & Sewerage **86**, 442 (1939).
[6]H. T. Hotchkiss, Water Wks. & Sewerage **92**, 1426 (1939).
[6]L. R. Stevens, Water Wks. & Sewerage **87**, 111 (1940).

APPARATUS FOR COLLECTING FLOCCULATED SAMPLES*

THE apparatus shown on the accompanying sketch consists of a wide mouth bottle clamped to a thin board, which in turn is attached to a pole of suitable length. The board is free to rotate on the center pivot and may be turned by the string or light chain attached to the two opposite corners. The bottle may be vented through tubing which extends above the liquid surface.

When the bottle is lowered in inverted position, the pinch clamp on the vent line is closed. When the desired sampling level is reached, the pinch clamp is released, so that the floc containing liquid slowly enters the bottle as the air is released. When the bottle is full it is rotated and then raised to upright position with the pull chain.

Through use of this apparatus, flocculated samples from any liquid depth may be collected. The breaking up of flocs, such as occurs when samples are pumped or taken by means of a small mouthed bottle, is avoided.



Acknowledgment

This device employed in studies made by the authors at Ypsilanti, Mich., was perfected by Mr. Geo. Darby, Director of the Westport Laboratories of the Dorr Company. It is a modification of a somewhat similar device earlier developed at the Howard Bend Purification Plant at St. Louis, Mo.

*Contributed by A. J. Fischer and A. Hillman, The Dorr Co., New York City. Printed in Water Works and Sewerage for April, 1940.

LAKESIDE ENGINEERING CORPORATION
222 W. ADAMS STREET CHICAGO, ILLINOIS

WATER FILTRATION AND PURIFICATION

PRESSURE FILTERS — GRAVITY FILTERS — ACTIVATED CARBON FILTERS OIL REMOVAL FILTERS — IRON REMOVAL EQUIPMENT — STERILIZERS

LAKESIDE FILTER CONSTRUCTION

The construction of a water filter consists of more than just the assembly of tanks, valves, fittings, gravel and sand. It involves the application of certain fundamental engineering principles which are obtained through long experience in the field. Lakeside filter construction embodies sound engineering practice including special exclusive features which produce far better results than are obtained in any other make of filter.

"Lakeside" filters are known for the very highest quality of materials and workmanship that enter into their construction. As a matter of fact, they are built to a quality standard, thus offering the purchaser equipment that will give maximum length of service at minimum cost.

TANKS. Pressure filter tanks are built of heavy steel with ample factor of safety to insure long life. Unless otherwise specified, riveted boiler flange steel construction is used. The vertical filter side shell is 60" high to provide sufficient room above filter bed to permit proper backwashing without loss of sand.

VALVES. Gate valves of the best grade of manufacture are used throughout. All valves necessary to perform the functions of an efficient filter both for downward filtration and upward backwashing are supplied. Note that backwashing may be accomplished with either filtered or unfiltered water.

PIPING. All external piping is galvanized steel unless otherwise specified. Internal piping is extra heavy. The pipe entering the filter above the sand bed is connected to the top head.

STRAINER SYSTEM. The collecting system in the base of the filter consists of a header pipe with properly spaced laterals. Long shank brass nozzles are uniformly spaced in the distributor system to insure proper water distribution. The entire distribution system is imbedded in concrete up to within the outlets of the brass nozzles. The throats of the brass nozzles are drilled of a size which will assure a small back pressure at each nozzle. The water passes out of the nozzles in a horizontal direction eliminating any possibility of jet action. Each horizontal opening in the nozzle is smaller than the main throat and the total area of the throats of all nozzles is slightly less than the cross section area of the header pipe.

FILTERING MEDIA. Properly graded silica gravel or graded machine-cut quartz is used as a supporting bed for the filtering media. The filtering media can either be silica sand or machine-cut quartz as the occasion demands.

The standard "Lakeside" filter bed consists of 4" of coarse graded gravel, 4" medium gravel, 4" fine gravel and 24" of washed and graded filter sand.

LOSS OF HEAD GAUGE. A duplex loss of head gauge is furnished with each filter 30" in diameter or larger in order that the operator may know when the filter requires backwashing.

SIGHT GLASS AND TESTING COCKS. A large positive operating sight glass is so placed on the sewer outlet line that it will show the condition of the effluent regardless of whether the water is flowing upward or downward through the filter to sewer. One testing cock is located in the effluent and another in the influent line for sampling of the water.

COAGULATING POT. One coagulant pot is furnished with each filter installation. Where the alkalinity of the water is not sufficient to permit of proper coagulation with the use of alum alone an additional pot can be supplied for the feeding of chemical to increase alkalinity.

RATE OF FLOW INDICATORS. Rate of flow indicators are not standard equipment, but we recommend their use in order that the operator can readily observe the rate or speed of backwashing. Such indicators can be supplied for a small additional cost.

AERO-FILTERS FOR THE HALVORSON-SMITH PROCESS OF SEWERAGE PURIFICATION

THEORY AND ADVANTAGES. The Aero-Filter is a device designed to distribute sewage on the filter bed in an even, continuous and rainlike manner. Both the rotary and the disc types developed by the Lakeside Engineering Corporation are based upon the fundamental principle that best filtration is obtained when the filter bed is evenly and entirely covered by a continuous **24-hour rain** of sewage, thus using **all** the bed **all** the time. The application of this theory by the Aero-Filter results in:

1. Excellent momentary distribution eliminating recirculation for dilution purposes.
2. Reduction in raw sewage B.O.D. ranging from 84% to 94% with single stage operation and from 88% to 99% with single stage operation followed by filtration or with two stage operation.
3. Low first cost since the Aero-Filter requires only 1/7 to 1/8 the size of a standard filter of equal capacity.
4. Lowest known operating costs.
5. Minimum troubles from odors, freezing, ponding and filter flies.

Results obtained by Excellent Distribution—not by Costly Recirculation

ROTARY TYPE—31' TO 84' DIA. FILTER. The number of arms, branches and nozzles is varied to fit the needs of the special problem. Further regulation is obtained by adjustment of the nozzles which can be made to discharge directly downward upon the filter, directly upward or in any intermediate position. The angle of discharge can also be changed to any point of the compass, and the orifice nozzles are easily interchangeable in the field. A Lakeside engineer will be present when these units are placed in operation to pan-test the filter bed and make the proper distribution adjustments.

DISC TYPE—8' TO 34' DIA. FILTER. The motor-driven disc distributors range in size from 12" to 34" in diameter and are designed to operate at from 260 to 360 r.p.m., the speed for any given size of filter being constant. The discs are divided into three equal segments, each segment being equipped with vanes for dividing the flow of sewage and shunting it uniformly over the filter bed.

ADVANTAGES: 1. The disc distributor will not clog and there are no nozzles to clean.
2. Satisfactory operation under widely varying rates of flow.
3. No mercury seals or packing glands to require attention.
4. Fool-proof construction, distribution is fixed by disc design and cannot be changed by the operator.

TREATING WATER TO PREVENT CORROSION

By JOHN R. BAYLIS

Associate Editor, Water Works & Sewerage

The writer, in 1930 presented some of the factors involved in preventing corrosion of water pipes.[1] Curves were given to show the solubility equilibrium of iron and zinc compounds in the presence of their respective metals. These curves (Fig. 1) show that practically no iron or zinc will exist in solution when the pH is above 8.0. At a pH of 7.0 several parts per million of either metal may exist in solution in some form in the absence of oxygen, and at a pH of 6.5 quite a large amount of iron or zinc may be found in solution in the absence of oxygen. The article explained how corroding iron took all the free CO_2 and much of the half-bound CO_2 from the water, leaving the water distinctly alkaline where there was no dissolved oxygen present. If the water contained dissolved oxygen the iron was precipitated as a hydrous oxide. Section of a 1-in. cement lined pipe, which had been in service for 50 years at Danvers, Mass., also was shown. The interior of the pipe was in fairly good condition, indicating that the lining was still giving very good protection.

Carrying Capacity of Pipes Greatly Reduced by Incrustation Resulting from Corrosion.—That the carrying capacity of iron pipes may be greatly reduced by tuberculation and incrustation as a result of corrosion is well known to most every one.

Haydock[2] describes how cleaning the tubercles or incrustation from several pipe lines increased the flow. One line carried only about one-half its theoretical capacity, and another about two-thirds. Cleaning a pipe line 3 miles long increased the capacity to the extent that a pumping station could be abandoned, and cleaning another line 5 miles long also enabled the abandonment of a pumping station. The friction loss through a 12-in. line 4 miles long 20 years old was nearly three times that of a new line. The capacity was increased by approximately 35 per cent and the delivered pressure by 20 lb. The gravity delivery of a 16-in. pipe 10.5 miles long was increased 60 per cent by cleaning. Cleaning a 13 mile section of a 12-in. pipe line 22 miles long, which had been in service about 16 years, increased the capacity approximately 35 per cent, and cleaning another section of the line 6 miles in length increased the carrying capacity to 46 per cent.

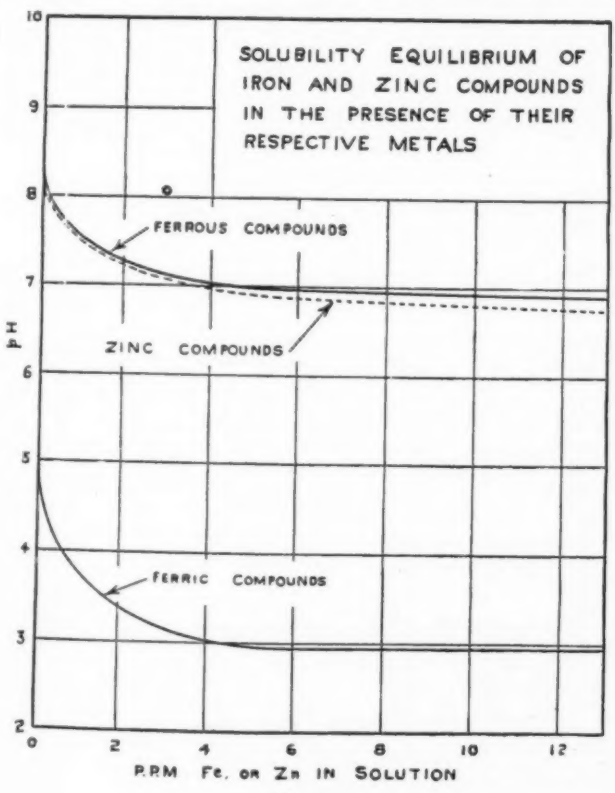

SOLUBILITY EQUILIBRIUM OF IRON AND ZINC COMPOUNDS IN THE PRESENCE OF THEIR RESPECTIVE METALS
FERROUS COMPOUNDS
ZINC COMPOUNDS
FERRIC COMPOUNDS
pH
P.P.M. Fe. or Zn IN SOLUTION

Fig. 1

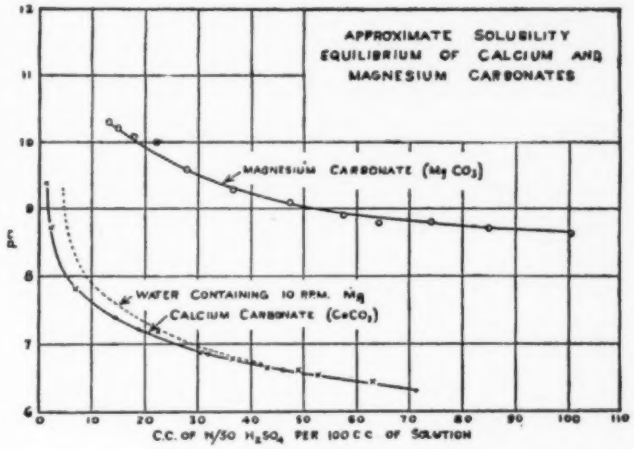

APPROXIMATE SOLUBILITY EQUILIBRIUM OF CALCIUM AND MAGNESIUM CARBONATES
MAGNESIUM CARBONATE ($MgCO_3$)
WATER CONTAINING 10 P.P.M. Mg
CALCIUM CARBONATE ($CaCO_3$)
pH
C.C. OF N/50 H_2SO_4 PER 100 C.C. OF SOLUTION

Fig. 2

Increased Pumping Pressure or Larger Mains Very Expensive.—In some instances it is possible to deliver the desired amount of water through distribution systems that have become partially clogged by increasing the pumping pressure as the friction losses increase, or to install booster pumping stations on the distribution system in certain sections where the pressure is low. Haydock refers to the delivered pressure being increased 20 lb. by cleaning the pipes in one instance. Assume that it was desired to maintain this 20 lb. increased pressure, evidently it was quite expensive to do it at the pumping station. A fair average of the cost of lifting one million gallons of water 1 ft. in height is probably 5 ct. Twenty pounds is equivalent to about 46 ft. in head. In this case it would cost about $2.30 per million gallons to maintain the increased pressure.

If corrosion is going to reduce the carrying capacity of the water mains in a certain city 50 per cent within 20 years, what is the best way of handling such a situation? Should mains be installed large enough to give the desired capacity with a 50 per cent reduction in carrying capacity? The cost of such an investment over what would be necessary if there was no corrosion very likely would be much more than the cost of making the water reasonably non-corrosive.

With the exception of feeder mains, engineers usually design the water distribution system for fire protection. How many engineers allow for a 50 per cent reduction in the carrying capacity of the pipes within 20 years where the water is corrosive? How many make any distinction whatever in the design where the water is corrosive and where it is not corrosive? The writer is of the opinion that corrosion has not been given its proper consideration in the design of water systems. This is largely due to the lack of specific information in the past as to how much the carrying capacity will be reduced within a certain time.

Treatment with an Alkali for Partial Protection.—The literature on the treatment of water to prevent corrosion indicates quite conclusively that the corrosiveness of water may be greatly reduced by proper treatment. It seems that some of the authors of articles on corrosion prevention do not fully realize the importance of a film for protection. So long as iron stains are prevented, some think that this is all the treatment that is necessary. As a matter of fact the carrying capacity of the pipes may be reduced just as rapidly as before, because most of the corroding iron is deposited near where the corrosion is taking place and forms large tubercles that are more effective in reducing the carrying capacity of the pipes than if the rust was

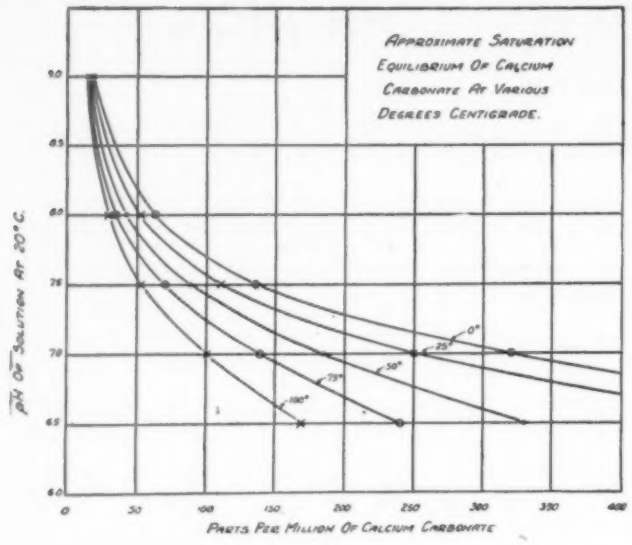


Fig. 3

deposited fairly uniform over the surface of the pipe. Treatment just to the point where red water complaints cease may not materially reduce the cost to the water department for cleaning pipes, constructing new mains, and increasing the pumping pressure.

Water Just Saturated with Calcium Carbonate s the Most Desirable Equilibrium.—As a general rule, it might be said that water saturated with calcium carbonate is the most desirable equilibrium when everything is taken into consideration. This is not strictly true for very soft waters, for it is desirable to have the water slightly supersaturated part of the time so as to form a thin protective film. Where the calcium carbonate alkalinity of the water is below 30 parts per million the application of lime to produce a slight supersaturation of calcium carbonate should be done with considerable care, otherwise caustic water might be produced. After a thin coating has been formed on the pipes the water should be kept saturated with calcium carbonate practically all the time to keep the coating from being dissolved. It is admitted that the very soft waters are the most difficult to protect, for we are working with equilibriums difficult to maintain exactly on the saturation point. It may be almost impossible to do this with the force available in small plants and it may be necessary to sacrifice some protection to avoid occasional caustic taste in the water. There is no reason why large plants with skilled supervision should not be able to maintain a fairly constant equilibrium.

Table I—Rapid Increase in pH Caused by Corroding Iron

Alkalinity	Time in Contact with the Iron Minutes	pH	Fe in Solution
39	0	7.2	
	1	7.3	
	2	7.4	
	3	7.7	
	5	8.2	
	10	9.2	
	15	9.4	
35	20	9.6	0.0tr

Where water has a calcium carbonate alkalinity in excess of about 30 it is easier to protect the pipes. If this water is placed in contact with an iron surface the iron going into solution will take up all the free Co_3 that is in the water and part of the half-bound CO_2. Table I shows how quickly the pH changes in water exposed to iron lathe turnings. After the pH reaches 8.1 no free CO_3 is present. This was due to the CO_3 combining with the corroding iron.

At any point on the surface of an iron pipe where corrosion starts to take place due to the surface becoming exposed in some manner, there is a tendency for the iron going into solution to take up the free and part of the half-bound CO_2, producing a supersaturation of calcium carbonate in the immediate point where corrosion is taking place. This supersaturation helps to quickly form a coating over the exposed surface both by precipitating the iron compounds and also some calcium carbonate, especially when the water has a fairly high alkalinity. If the water in the mains is saturated with calcium carbonate, then the precipitated calcium carbonate will not be dissolved out of the percipitate. It will remain where it is precipitated to offer protection against further corrosion.

Most natural waters contain magnesium carbonate as well as calcium, and the presence of a considerable amount of magnesium may materially alter the equilibrium curve. This is shown by the curves in Fig. 2. The presence of sodium carbonate also alters the curve. When sodium carbonate is present the only way the saturation equilibrium of the water in regards to calcium carbonate can be determined is by actual trial.

Temperature also has an effect upon the saturation equilibrium of calcium carbonate. The curves shown in Fig. 2 were determined at room temperature, that is, about 20 to 22° C. The other curves are based on actual tests, but not enough were run to state that the curves are absolutely correct. They should be regarded as somewhere near the true lines.

Corrosion prevention by treatment of the water has been demonstrated to be practical and economical. This being true, then it seems that all corrosive waters should be treated.

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[1]Baylis, J. R. How to Avoid Loss by Pipe Corrosion. Water Works Engineering, 83:13-14, 31-32, 35-36, Jan. 1, 1930.

[2]Haydock, C. The Cleaning of Cast Iron Water Pipe Lines Jour. Am. Water Works Assoc., 11:533-4, May, 1924.

The Influence of Dissolved Oxygen on Corrosion Losses

Engineers and chemists are constantly studying the theories and mechanics of corrosion because it is only through better understanding of fundamentals that they will be able to diminish losses due to corrosion.

Thirty years ago, R. W. Whitney, now vice-president of the general Electric Company, announced that the corrosion of metals was an electrochemical process and this view is now generally accepted. When a metal is in contact with even slightly acidic solutions, corrosion takes place by the chemical process of the metal replacing the hydrogen in the acid. The acid dissolves the metal and thereby hydrogen is released. The same holds for corrosive waters.

Released hydrogen coats the metal surface with an electrically charged layer that prevents the chemical reaction from continuing at the initial rate. If the hydrogen layer is built up to a sufficient thickness the reaction is practically stopped. However, under natural conditions, the hydrogen combines with the oxygen of the air or that dissolved in the water to form water and solution of the metal goes on. The *amount of oxygen* available to remove the protective hydrogen blanket determines the extent of corrosion.

Impure metals are corroded more quickly as a rule than pure metals. Electrochemists believe that this is due to the impurities taking up the oxygen. Contrary to the popular belief, however, pure metals are subject to corrosion under the action of certain acid solutions. Prof. O. P. Watts of the University of Wisconsin has recently shown that if oxygen is absolutely excluded copper will not corrode in a solution of sulfuric acid, a reaction that is very rapid in the open.

The importance of the dissolved oxygen content of corrosive water is thereby once more emphasized. When this element is present in high concentration a higher pH value must be maintained to prevent corrosion of mains than otherwise; and, particularly of household services or piping subjected to increased temperatures which create accelerated attack.

This suggests that there is some question as to the merits of aeration of waters which are normally aggressive, unless the pH value is raised sufficiently by alkali addition to reduce the hydrogen ion concentration considerably; below that which is commonly considered to represent a neutral water. It has in fact been demonstrated that ofttimes waters high in oxygen content and low in hardness must be raised to pH 9.5 in order to check even the cold water corrosion of mains. In some aerated waters a pH value of 10 to 10.5 is required, which is costly and questionable practice with public supplies.

CALGON, INC.

A Subsidiary of Hagan Corporation

calgon *Associated with Hall Laboratories, Inc. and The Buromin Company* calgon

Hagan Building, Pittsburgh, Pa.

Specialists in the Application of Glassy Sodium Phosphates to Industry

CALGON TREATMENT

Solves Four Major Water Works Problems

1. Controls Corrosion

Calgon maintains a thin, protective film over metals and metal oxides at pH values of 5.0 and higher, reducing the attack of oxygen to such an extent that corrosion ceases to be a serious problem and "red water" from corrosion is eliminated.

2. Prevents "Red Water"

Calgon added to well water as it is pumped prevents the precipitation of dissolved iron and so prevents "red water" from this source, whether oxidation is due to exposure to air, aeration during iron removal, or chlorination.

3. Stabilizes Water Following Lime Softening

Calgon added after the softening process effectively controls excess calcium carbonate in solution, which otherwise forms scale in water lines and hot-water heaters. Calgon stabilizes water throughout the system—at any pH value—and eliminates precipitation of calcium carbonate scale in hot-water heaters.

4. Prevents Scale Formation from Hard Water

Where water is high in bicarbonate alkalinity, the use of Calgon at the plant affords a simple, economical means of stabilizing water and eliminating precipitation of calcium carbonate scale in consumers' heater coils, tanks and hot-water lines.

Calgon Characteristics

Calgon is a complex sodium phosphate glass produced by a thermal process from food-grade phosphoric acid and soda-ash. Readily water-soluble, unadjusted Calgon glass has a pH of approximately 6.0 in 1 per cent solution. Impurities and moisture total less than 0.2 per cent.

Calgon is as harmless as table salt; even in amounts many times greater than those employed in municipal water treatment it produces no adverse physiological effect.

Calgon Treatment

The amount of Calgon used in treatment is extremely small . . . from 1 to 5 parts per million of water. Since little or no equipment is required, the total cost is well within the budget of most water departments. Calgon Treatment is a sound, accepted process which corrects water troubles without introducing new ones. It is now being used successfully in more than 500 municipal water systems, ranging in capacity from 10,000 to 120,000,000 gallons per day.

Whether your problem is stabilization of softened water, corrosion control, "red water" from dissolved iron, or hard, high-bicarbonate water, Calgon can help you. Technical information on specific water problems and a free sample of Calgon* for laboratory test purposes will be furnished on request.

**Calgon is the registered trade-mark of Calgon, Inc., for its glassy sodium phosphate products.*

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Charlotte—Eshelman and Potter, 314 Wilder Bldg.
Chicago—Burke & Colston, 1316 Austin Bldg.
Cincinnati—L. I. Snodgrass Co., 18 East 4th Street.
Cleveland—Chas. H. Tate Co., 404 Newman Stern Bldg.
Denver—Denver Fire Clay Co., 2301 Blake Street.
Detroit—Calgon, Inc., 2512 Book Building.
El Paso—Denver Fire Clay Co., 209 Mills Bldg.
Franklin, Pa.—Alfred Watson, 107 Fourteenth Street.
Houston—Maintenance Engrg. Corp., 3611 Clinton Drive.
Kansas City, Mo.—H. O. Halden, 221 Plaza Theater Bldg.
Los Angeles—Calgon, Inc., 1807 E. Olympic Blvd.
New York—Simler & Sengstaken, 271 Madison Avenue.
Philadelphia—Ash Engineering Co., 225 South 15th Street.
Pittsburgh—Calgon, Inc., Hagan Bldg.
St. Louis—Calgon, Inc., 1208 Continental Bldg.
St. Paul—Fuel Economy Engrg. Co., 510 New York Bldg.
Salt Lake City—Denver Fire Clay Co., 225 W. So. Temple St.
San Francisco—Calgon, Inc., 149 California St.
Seattle—Northwest Filter Co., 122 Elliott Avenue West.
Toledo—Power Equipment Co., Oak Harbor, Ohio.

Canada

Montreal—
Dominion Flow Meter Co., Ltd., 515 New Birks Bldg.
Toronto—
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Mexico, D. F.—
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"CHEMICAL FEEDER HEADQUARTERS"

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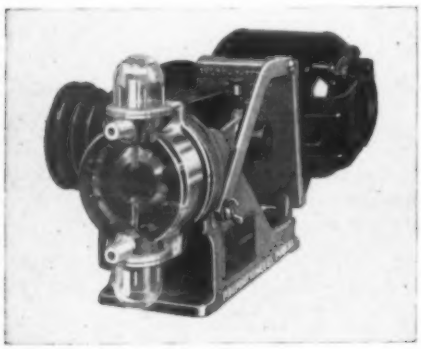
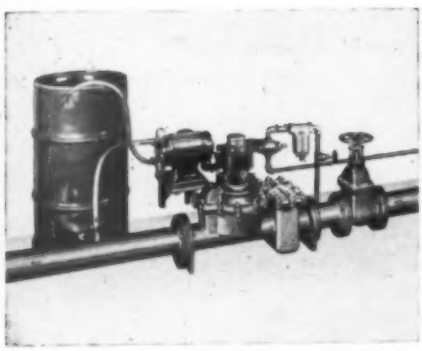
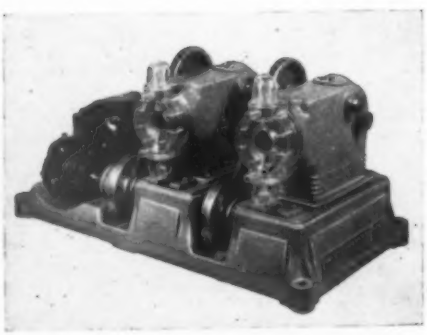
PRODUCTS — Single or Multiple Chemical Feeders for water and sewage plants, the military, and industry; and engineering service on proportioning problems. Feeders are of positive-displacement solution-feed type. For constant rate or proportional feed with mechanical or hydraulic operation. Chemical solutions handled with "See-Thru" transparent plastic reagent end construction include: Sodium or calcium hypo-chlorite, aqua ammonia, soda ash, alum, ferric chloride, ferric sulphate, calgon, sodium aluminate, copper sulphate, sodium hydroxide, dilute acids, etc. Other construction for concentrated Sulphuric acid and hard to handle chemicals.



Chlor-O-Feeders in Water Works Service for Sterilization (Hypo-Chlorinators)—Midget Chlor-O-Feeders (diaphragm or piston type for low or high pressures) for pumped water supplies are the most dependable and least expensive, most accurate and least complicated feeders available for chlorination of up to 1½ million gallons per day. The Chlor-O-Feeder is small, easily and quickly adjustable to various feeding rates; driven by electric motors or belt driven from water pump. Installation is simple with aid of our complete instruction manual.



Proportional Chlor-O-Feeders for Gravity Water Systems — For many conditions, especially in gravity systems from reservoirs, where flow rates vary considerably from hour to hour, it is essential that the Chlor-O-Feeder be controlled by the flow of water so that the amount of solution injected is at all times in proportion. Proportional Chlor-O-Feeder can be mounted on and controlled by any flow-responsive device, standard water meter of any size or type; flow-responsive rotor; Venturi tube; orifice plate or even the reciprocating parts of deep-well pumps can be used to "pull the trigger" that sets off the chlorinating discharge. This Chlor-O-Feeder can be operated at any point where the water line can be cut to allow installation of meter. It can be operated entirely by water pressure, so does not require expense of wiring. Operation is simple, not needing expert attendants.



Calgon Feeding and pH Control—pH control by proportioning lime, soda ash, sodium silicate, sulphuric or other acids, is made simple by the use of these flow-proportional chemical feeders. Highly successful installations, designed by leading engineers, are providing permanent relief from plugged and corroded pipe lines. The growing use of Calgon in water works corrosion control finds frequent use of Calgon-Feeder for feeding sodium hexametaphosphate.

CALGON TREATMENT*

As Applied in Water Quality Control for the Solution of Four Problems

By OWEN RICE
Calgon Inc., Pittsburgh, Pa.

CALGON is a molecularly dehydrated, glassy phosphate commonly known as hexameta-phosphate and usually given the formula $(NaPO_3)_6$. It is easily dissolved and fed by any solution feed device. For the past ten years it has been of interest and of increasing importance in many phases of water treatment. Its use in several hundred plants during the last six years has shown that the continuous application of small amounts of Calgon to municipal water systems overcomes many of the problems commonly encountered.

Calgon prevents the precipitation of calcium carbonate from lime or lime-soda softened water as well as from hard waters high in bicarbonate alkalinity. Its addition to well water prevents the precipitation of dissolved iron therefrom, while its addition to any water reduces corrosion throughout the system. At first glance, these various applications and effects do not seem related but the result obtained in each case appears to be due to the adsorption of the Calgon on the surfaces of the metals, their metallic salts and oxides involved.

Stabilization of Water After Lime or Lime-Soda Treatment

After-precipitation of calcium carbonate from lime or lime-soda softened water has been a problem ever since the first softening plants were placed in operation. Although after-precipitation can be prevented more or less completely by recarbonation, the limits between which such a treatment must be maintained are very narrow and, although scale may be prevented in this manner, corrosion often results particularly in hot water heaters.

The addition of 1 or 2 ppm. of Calgon completely prevents after-precipitation from lime or lime-soda softened water.[1] It is believed that the metaphosphate is adsorbed on the crystal nuclei of calcium carbonate as rapidly as they form in the water, thus isolating each nuclei from further contact with the water and preventing its growth. This property of Calgon brings about the stabilization of a supersaturated water, from which calcium carbonate would otherwise precipitate.

The addition of Calgon to the water passing to the filters will keep the sand and underdrainage system free from incrustation. In cases where the additional softening effect obtained by the removal of some of the hardness on the filters is desired, the metaphosphate should be added to the clear well. Stabilization with Calgon will result in mains, meters, and hot water systems remaining free from calcium carbonate scale.

Precipitation of $CaCO_3$ from Hard, High Bicarbonate Waters

Calgon has the same stabilizing effect on waters which are naturally hard and high in bicarbonate alkalinity. Where ordinarily the loss of CO_2 or an increase in temperature would cause the formation of scale, this deposition is prevented by the presence of small amounts of Calgon.

Calgon treatment has proven entirely successful in preventing scale formation in hot water heaters with waters up to 1400 ppm. hardness and 600 ppm. bicarbonate, and at temperatures up to the atmospheric boiling point. At the most, an addition of 3 ppm. is required while, under less severe conditions, 2 or even 1 ppm. has proved sufficient.[2]

Preventing Dissolved Iron Precipitation

The action of Calgon on iron in solution is akin to that with calcium carbonate. Precipitation is prevented, thus eliminating "red water." In order to obtain this action, it is necessary to add the Calgon before the iron has had any chance to come into contact with the air. Therefore, in the case of well water supplies it is always best to add the Calgon at the suction side of the pump.

The addition of Calgon in a ratio of 2 ppm. of Calgon for each ppm. of dissolved iron is sufficient to hold the iron in solution even when the water is later aerated or chlorinated.[3]

Corrosion Control with Metaphosphate

Metallic iron when exposed to water dissolves to a considerable extent Any method of corrosion control depends, therefore, on the formation of an insoluble coating on the surface of the metal.

As mentioned above, Calgon has the ability to coat out on metal or metal oxide surfaces. As the metaphosphate is adsorbed on the iron surfaces of the mains in a distribution system, it forms an iron phosphate film which effectively seals the metal from the water. This film is formed at all pH values above 5.0 so that when using Calgon it is not necessary to add any additional chemicals to change the pH. Also since the film is formed by adsorption and not precipitation, the coating is formed throughout the entire system and not just near the plant.

The addition of Calgon in decreasing corrosion is in no way due to reaction with the water. The water simply acts as a carrier to bring the Calgon in contact with the metal or oxide surface upon which it is adsorbed. Since it is the adsorption of the metaphosphate on the surface of the metal which prevents corrosion, the necessity of supplying sufficient Calgon to meet the requirements of the system is obvious. This can be done either by using a relatively high concentration of Calgon in a small quantity of water or lower concentrations in larger quantities of water. This latter condition is the one which exists in all but the smallest municipal water systems.

In cases where corrosion is severe, it has been found that high initial feeds of Calgon—5 to 10 ppm.—are very helpful in more promptly forming the protective coating in the system. After equilibrium has been reached and the protective coating has been formed, the Calgon can usually be reduced to very small amounts, 1 to 2 ppm., and still be sufficient to maintain the protective coating initially formed.[4]

Summary

Calgon is easily dissolved and fed by any liquid feeding device. It is inexpensive because of the small quantities required and is easy to control. It has proven entirely successful when used in each of the above mentioned applications. Excellent results have been obtained in preventing the after-precipitation of $CaCO_3$ from lime or lime-soda softened water. Hot water heaters are being kept free from scale when hard high bicarbonate waters are used. Dissolved iron has been kept in solution, and the film of metaphosphate formed on the metal surfaces in the system has successfully prevented corrosion and all at concentrations of only a few ppm.

REFERENCES

1. Hoover, Charles P., and Rice, Owen. "Threshold Treatment." *Water Works and Sewerage*, 86: 10 (January, 1939).

2. Rogers, M. E. *Journal of American Water Works Association*, 33: No. 7, 1233-1241 (July, 1941).

3. Rice, Owen, and Hatch, G. B. "Threshold Treatment." *Journal of American Water Works Association*, 31: No. 7, 1171-1185 (July, 1939).

4. "The Value of Sodium Hexametaphosphate in the Control of Difficulties Due to Corrosion in Water Systems"—Committee W-8. *Journal of the American Water Works Association*, 34: No. 12, 1807-1830 (December, 1942).

5. I. Laird Newell. "Experiences With Calgon Treatment at Bristol, Conn." *Water Works and Sewerage*, 89: 269 (June, 1942).

[*A summarial statement prepared for the Reference and Data Section of "Water Works and Sewerage" by Mr. Rice at our request.—*The Editors.*]

WILSON CHEMICAL FEEDERS, INC.

Manufacturers of Pulsafeeders for
Chemical Solution Water Treatment

BUFFALO, NEW YORK, U. S. A.

THE WILSON "PULSAFEEDER"

is a positive displacement, pump type chemical solution feeder; designed primarily for the feed and accurate control of both corrosive and "hard-to-handle" chemicals.

Basically PULSAFEEDER is in the family of accurate piston pumps. However, it is also equipped with a diaphragm to actually separate the chemical solution being pumped, from all operating or moving parts. No packing glands are used, and the diaphragm has no mechanical connections.

Low pressure models of PULSAFEEDER handle solutions against pressures up to 200-lbs. per sq. in. High pressure models are good up to 1500-lbs. per sq. in. Sizes are available up to 400-gals. of solution per hour.

CHEMICAL SOLUTION WATER TREATMENT

HYPO-CHLORINATION

The PULSAFEEDER was originally designed for use with either calcium or sodium hypochlorite. A complete treatment system is available for either manual, semi-automatic or fully automatic operation. Feeds all concentrations; supplies up to 500,000 gals. of water per day.

COAGULATION

Accurate control of coagulation chemicals for water or sewage filtration, employing use of aluminum salts, iron salts and the like. Units available in capacities up to 400-gals. per hour.

pH CONTROL

PULSAFEEDER's principal of chemical solution isolation allows for feed of all concentrations of acids and alkalis. Guarantee of not more than ⅛ of 1% feed variation assures accurate pH control.

CALGON FEEDING

Scale prevention, iron control, corrosion control all handled expertly by PULSAFEEDER. Hundreds of units are in use in water supplies of all types and sizes.

ODOR, TASTE AND COLOR CONTROL

Problems involving odor, taste and color control are all within the scope of WILSON PULSAFEEDERS. Write us for recommendations.

OTHER USES

PULSAFEEDERS are also adapted to many processing problems, food equipment sterilization, boiler chemical feed, automatic blending operations, and other accurate proportioning problems.

Manual and Fully Automatic PULSAFEEDERS

The various PULSAFEEDERS use either electric motor, gasoline engine, water or air motor drives, and are controlled by water meters of all types if flow-proportional feed is desired. The types below represent a complete line of chemical water treatment apparatus.

MANUAL

Type DES—
Electric motor driven simplex model, for feed of a single chemical solution.

Type DED—
Electric motor driven duplex model, for feed of two solutions. Used widely for chloramines.

Type DET—
Electric motor driven triplex. Generally used for hypochlorite, soda ash and alum. For feed of three solutions.

Type DEQ—
Electric motor driven quadruplex. For feed of four solutions simultaneously, each feed independently adjustable while in operation.

Type DEG—
Emergency portable model for water sterilization. Feeds against 200-lbs. per sq. in. Capacity 300-lbs. chlorine per 24 hours.

AUTOMATIC

Type MC-DES—
Electric motor drive, meter controlled. Applicable to all liquid meters. Single and multifeeders.

Type MC-DS—
Water or air motor drive, meter controlled. Applicable to all meters. Single and multifeeders.

Type MC-WD—
Water or air motor powered, meter controlled, marine type. For installations aboard ship.

Type SP—
Flow-proportional, pressure differential feeder for operation with orifices, flow nozzles or venturi. Operates on 1" water differential and up.

CHECKING TUBERCULATION BY CHLORAMINE TREATMENT

By J. WALTER ACKERMAN*

Water Production Div., War Production Board, Washington, D. C.

The results from the ammonia-chlorine treatment in suppressing tuberculation of the 12-mile cast-iron supply main at Utica, N. Y., constitute a new chapter in corrosion control and depreciating capacity values of water mains.

When Mr. Ackerman first reported his observations informally before the American Water Works Association in 1934, he considered the findings both interesting and indicative, rather than conclusive. Amongst his audience were many skeptics. A year later sufficient supporting data had been accumulated by him to warrant a further informal report before the same association. Now, still a year later, the results are more than ever convincing. It was with thtis in mind that WATER WORKS AND SEWERAGE *asked Mr. Ackerman to present to its readers his data-graphs and the accompanying report of the continuing effectiveness of the treatment which maintains sterile conditions throughout the 12-mile main.—Editor.*

The Consolidated Water Co. of Utica, N. Y., constructed in 1906 a single 24-inch cast iron water main for transmission purposes to bring water from the West Canada Creek at Hinckley, N. Y., to Marcy Summit, a distance of 12.1 miles, for the purpose of supplying the city of Utica with water from this source in addition to that already supplied from the southern group of reservoirs. This supplied sufficient water for use in the city until 1922, when the use had increased and delivery of this line had diminished to a point where it was only delivering about 8.5 M.G.D.

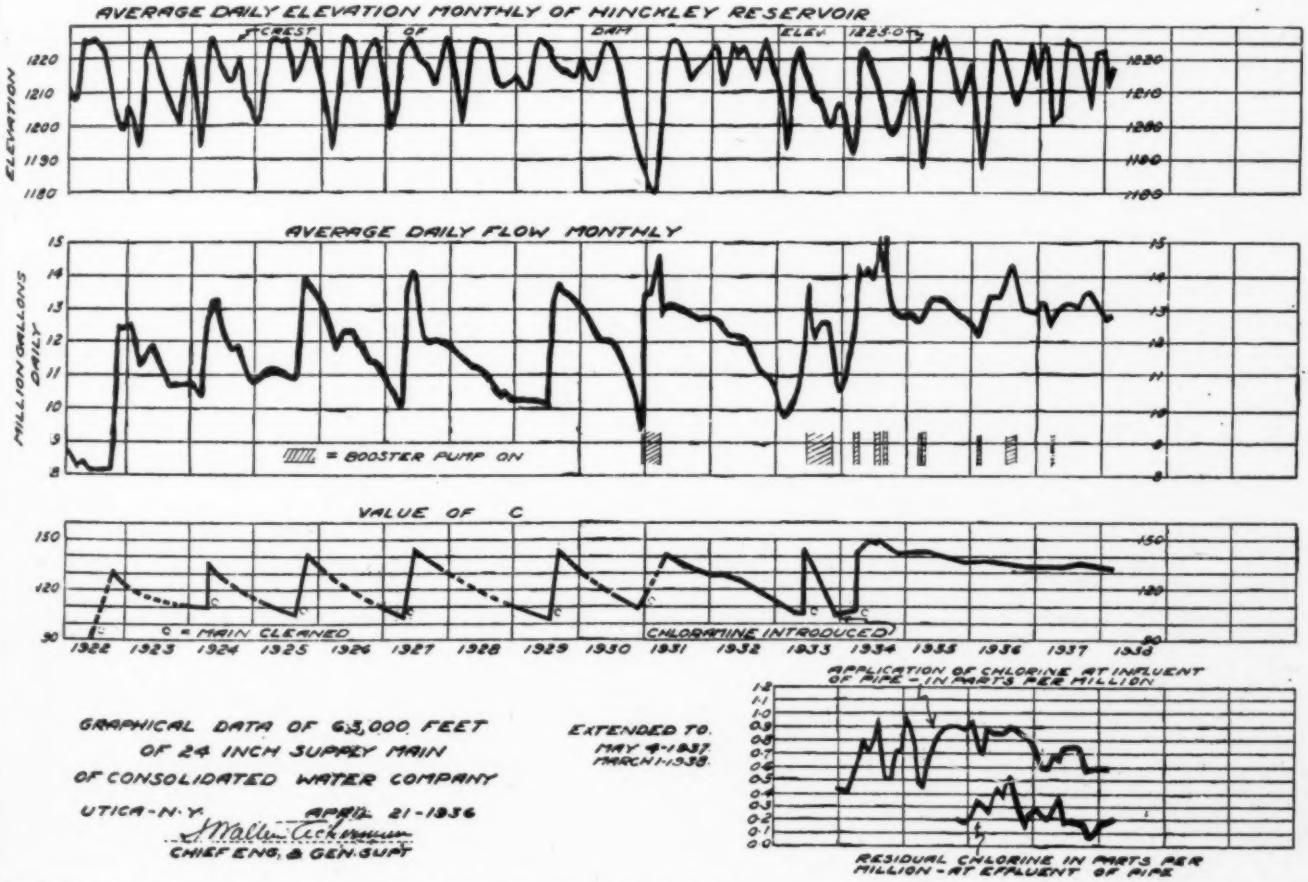
**General Superintendent, Consolidated Water Co., Utica, N. Y., when this article was written.*

Records in the office indicate that in 1917 this line was examined by Metcalf & Eddy, Engineers, and the value of "C" in the Hazen-Williams formula was found to be 109. On July 5, 1921, "C" had dropped to 95, and in November of the same year it had dropped further to 93.5. It later became necessary to clean this line and the National Water Main Cleaning Company was engaged for this purpose and cleaned it on October 5, 1922.

Table A shows the number of times the main has been cleaned since that date and the various "C" values before and after cleaning.

TABLE A

Date Cleaned	Months Since Previous Cleaning	Reservoir Elevation	—Delivery— Before	—Delivery— After	——"C"—— Before	——"C"—— After
		1199.9	Oct. '22	Oct. '22	June '22	Oct. 8, '22
Oct. 5, 1922		1199.9	8.5	12.3	90	131
		1192.3	Mar. '24	May '22		
Apr. 1, 1924	18	1226.1	10.3	13.2	109	136
		1211.8	Aug. '25	Oct. '25		
Aug. 27, 1925	17	1220.4	10.5	13.9	106	142
		1222.7	Apr. '27	June '27		
May 4, 1927	20	1223.1	10.1	14.2	103	144
		1223.7	July '29	Sept. '29		
Aug. 6, 1929	27	1215.6	10.0	13.8	102	142
		1193.3	Nov. '30	Mar. '31	Nov. '30	Sept. '31
Jan. 3, 1931	17	1249.7	10.2	14.6	109	133
		1223.6	May '33	July '33	Apr. '33	July '33
June 16, 1933	29	1273.8	10.3	14.0	106	136
		1276.4	Apr.2,'34	Apr.12,'34		
Apr. 8, 1934	10	1226.1	11 9	13.7	111	144


AVERAGE DAILY ELEVATION MONTHLY OF HINCKLEY RESERVOIR
CREST OF DAM
ELEV. 1225.0
ELEVATION
1220
1210
1200
1190
1180
AVERAGE DAILY FLOW MONTHLY
MILLION GALLONS DAILY
= BOOSTER PUMP ON
VALUE OF C
C = MAIN CLEANED
CHLORAMINE INTRODUCED
1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938
GRAPHICAL DATA OF 63,000 FEET OF 24 INCH SUPPLY MAIN OF CONSOLIDATED WATER COMPANY
UTICA-N.Y. APRIL 21-1936
CHIEF ENG. & GEN. SUPT
EXTENDED TO MAY 4-1937 MARCH 1-1938
APPLICATION OF CHLORINE AT INFLUENT OF PIPE - IN PARTS PER MILLION
RESIDUAL CHLORINE IN PARTS PER MILLION - AT EFFLUENT OF PIPE

Graph Showing Effectiveness of Ammonia-Chlorine Treatment in Sustaining the Carrying Capacity of a Cleaned CI. Main 12.1 Miles in Length. Compare the Friction Coefficient Curve for 1930 and 1934 with that for 1934-1938

Until December, 1933, this 24-inch line had carried nothing but untreated water, chlorination being carried out at the local distributing reservoirs. In December, 1933, chlorine-ammonia treatment of the water was started at Hinckley, and the "C" value at the time the treatment began was 105. In April, 1934, just prior to the last cleaning, a measurement of "C" showed a value of 111, an apparent improvement of about 6 p.c. in carrying capacity after the four months of treatment by chloramines, without cleaning.

The last cleaning of this line was done as noted on April 8, 1934, and the "C" value was raised from 111 to 144. No mechanical cleaning has been done since that date, but the line has been continuously treated with chloramires to the present time

The graph accompanying this artic'e sl.ows the variations in the level of the water in the Hinckley Reservoir, which varies the head on this pipe line and consequently varies the flow due to this change in head. It shows the monthly average flow in each month from 1922 to date, also the chlorine application and the resultant "C" value before and since the application of the ammonia-chlorine treatment. The results seemingly speak for themselves.

Method of Checking "C" Value

Just a word as to the method of checking this "C" value. Careful and rechecked determinations of reference level points at each end of the 12.1 miles of pipe have been made. Consequently, physical observations of the water level in the standpipe at one end of the line and the water level at Hinckley Dam at the other end give the actual slope. The amount of flow is determined by a venturi meter, but at no time has the value of the amount of flow been accepted except after being checked by manometer or pitot tube, and, in fact, a number of these determinations are made either by the manometer on the venturi tube or the pitot tube near this same place Therefore there are some slight variations in the determining of the "C" value of the period from April, 1934, to the present time. While there appears to be somewhat of a downward trend, it is so small as to be almost negligible, as, of course, the different methods of computing the flow vary about 2 to 3 per cent, according to the method used for this determination, which is as close as can be expected for equipment of this nature.

The Marcy standpipe, which is at the lower end of the 12.1 miles of 24-inch pipe in question, is 2.3 miles from Marcy Reservoir, where the actual chlorine residual is taken, as the Marcy standpipe is in a more or less inaccessible location a part of the year. The residual obtained and shown on the chart is less, therefore, than the actual residual at the end of the 12.1 miles of 24-inch pipe, as the chlorine demand in the 2.3 mi'es to Marcy Reservoir is considerable in this uncleaned and badly tuberculated section of pipe, which we believe is gradually being cleaned by the action of the chloramines.

Addenda—1937-1938

The above article was prepared in April, 1936. From Mr. Ackerman comes the following advice and a new graph, which carries forward the flow and friction data into 1938, although the graph carries the original date—April 21, 1936. The author explains that the data are checked by frequent readings taken from a checking manometer on the venturi tube, and the use of a Cole rod and Lanham rod. These check readings have shown a difference of but 1 to 3 points in obtaining "C" values of 134 to 142 in the Utica situation.

Mr. Ackerman states: "It will be noted that there seems to be a slight diminution of the "C" value during the past year, but hardly enough to make very much difference in our flow. As a matter of fact we are actually getting more water down now than heretofore, which, I think, is due to the fact that all of these figures constitute the result between the Hinckley Dam and our Marcy standpipe only."

"Below the Marcy standpipe to our reservoirs are two lines of pipe, one 24-inch and one a 16-inch. We know that the 16-inch is very badly tuberculated. About three years ago a test was made on it and the "C" value was down to about 60. But, since we had at least a theoretical capacity greater than the line above, we did not clean these two lines. We do find now that the water does not stand as high in our standpipe with the same dam elevation at Hinckley as heretofore, which rather indicates that the chloramines have been gradually cleaning the 16 and 24-inch lines below the Marcy standpipe."

"These are just some added points to give you a better understanding of the problem."

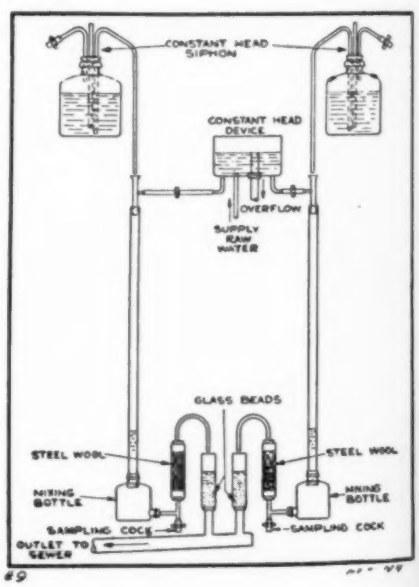
CORROSIVITY INDICATOR

THE accompanying sketch pictures a very effective piece of equipment devised and employed by Hall Laboratores, Inc., to study and demonstrate the efficacy of various treatments applied to waters for corrosion or scaling control.

The scheme involves passage of the water under treatment, for comparison, upwards through clean, bright steel-wool. The effluents leaving the wool contact chamber drips through clean glass beads.

The rapidity and relative intensity with which the steel rusts and the beads become iron-stained constitute a convincing semi-quantitative index of corrosivity. For greater exactness in comparison samples of effluent from the steel corrosive chamber are analyzed for iron, oxygen, etc.

It is evident that this apparatus can be employed with lead wool, copper-sponge, etc., to study action on these and other materials. A battery of as many units as required may be set up. The device has considerable resemblance to the Enslow Carboneous Stability Indicator.



SOME PRACTICAL ASPECTS OF HANDLING CHLORINE

By CHRIS F. BINGHAM*
Columbia Alkali Corporation, Philadelphia, Pa.

THERE appeared in the September, 1935, issue of the Journal of the American Water Works Association a valuable report, dealing with chlorine, by the Committee on Chemical Hazards in Water Works. This paper is intended to record various practical experiences in chlorine handling and opinions that in their nature had no place in the above committee report. However, the writer will quote freely from the report, where deemed advisable, and recommends that those interested procure a copy of the journal containing it.

Properties of Chlorine

Chlorine gas is approximately two and one-half times as heavy as air at normal temperature and pressure, and hence, leaking chlorine, tends to settle and collect in low places and on the floor of an enclosed room.

Chlorine is neither flammable nor explosive. The dry gas does not attack iron, copper, or lead at ordinary room temperature. However, in the presence of moisture it is very corrosive and combines readily with most metals except those classed as the "noble" metals and special alloys. It is important to note that even the dry gas becomes very corrosive at temperatures above 300 degrees F. and is likely to become so at temperatures as low as 195 deg. F.

Chlorine Lines

Rubber and the noble metals are sufficiently resistant to the action of wet chlorine to be satisfactory material to handle either the moist gas or water solutions. Liquid chlorine in itself cannot, however, be used with hard rubber. During the last year and a half plant tests have been made in Richmond to determine the resistance of asbestos-cement pipe to chlorine solutions. As a result, the prechlorination and copperas-chlorine solution systems have been rebuilt using two and one-half inch "Transite" Class "B" pipe and Class "S" elbows. So far, this installation has given excellent service, the only difficulty encountered was due to its brittleness and the lack of sufficient mechanical support—a few sections of the pipe being broken by strains before adequately supported. The chlorine solution seems to "wet" the inside of the pipe to a depth of ⅛ to 3/16-inch and then stop, no further change was noted in the experimental installation or in the new permanent installation after two months of heavy use.

Extra heavy iron pipe with wrought iron fittings and litharged joints should be used for the chlorine pressure lines. Litharge that has been opened for some time seems to form a carbonate coating on the particles which result in a never-hardening and oily joint compound which will allow the joint to leak probably. Only new litharge is recommended. Care taken in the correct installation of pressure feed lines is a thousand fold repaid. Ammonia valves (of steel) have been used in the chlorine pressure lines at Richmond with satisfactory results, but where possible the standard Chlorine Institute ton container valve has been used because of its convenience, economy and superior construction. In general chlorine needle valves should have either Hastelloy "C" or Monel Metal stems, and joint valve bodies may be constructed of steel, brass or Hastelloy "C."

Soft copper tubing connections (cadium plated) are used in connecting the one-ton chlorine containers to the piping system. We specify that a small wrench "ho'd" be milled on the bushing on the tubing, to allow holding the tube at the joint during tightening of the coupling. This, to prevent wringing off the tube at that point. The tubing becomes quite hard and rigid after continued service, but its ductility may be renewed by heating slowly to a dull red heat and quenching in water—the customary method of copper softening.

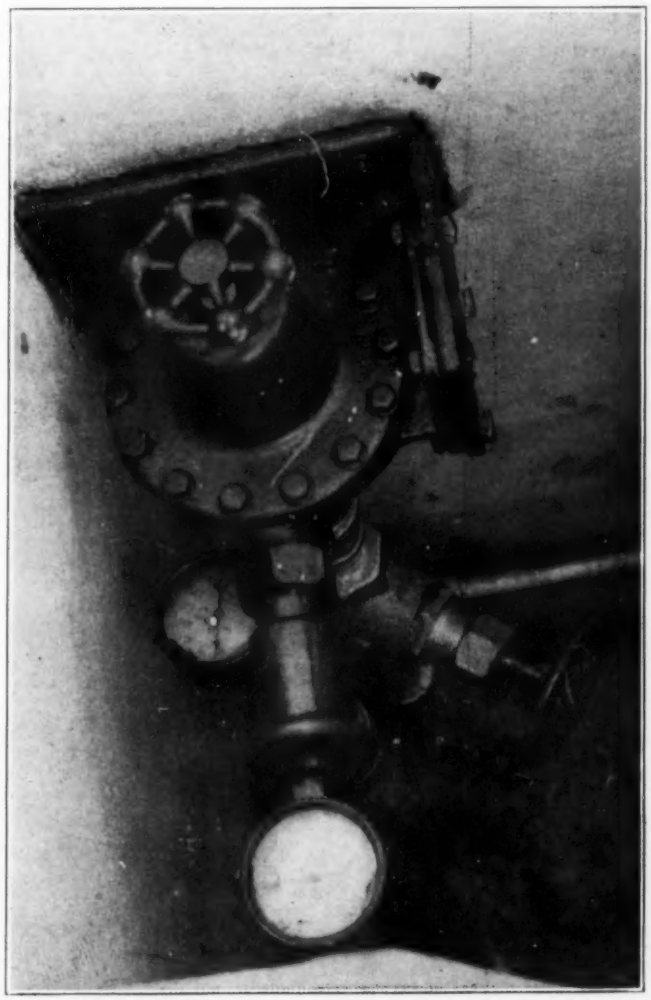
Hard drawn copper fittings and pipe of the "Streamline" type also have been used with essentially *pure* silver as the solder instead of the regular solder, furnished for such pipe, which chlorine attacks. A silver coin will serve as satisfactory solder. High copper content brass fittings have been used with this type of pipe also and seem to work entirely satisfactorily.

*Plant Supt., Div. of Filtration, Dept. Public Utilities, Richmond, Va., at time of preparation of this article.

Avoiding Condensation Troubles

The gas feed lines should, if possible, always be warmer than the chlorine containers to avoid condensation (reliquefaction of chlorine) and consequent problems. These lines should also be run on a continuous upgrade from the containers in order that the condensed liquid chlorine will flow back to the containers. Such theoretical conditions cannot always exist practically and, in cases where this is impossible, drip-legs should be provided at every low point on the pipe line—especially so near the chlorinators. Blow-off cocks or other bleeding arrangements are not recommended since they are both dangerous and unnecessary. If the drip-legs are so located that the room temperature does not keep the condensate vaporizing at a satisfactory rate, additional heat may be applied by warming with a 100-watt electric bulb permanently installed beneath the leg. The size of the leg varies with the conditions, but it is recommended to be 1¼ times as large as the volume of the pipe line leading from the chlorine container to the leg.

Chlorine reacts with grease and oil to form voluminous frothy substances; with gasoline and other petroleum distillates to form solid complex chlorinated hydro-carbons. Alcohol and ether, even in traces, are converted to solid waxy hexachloroethane. It is important, therefore, that all grease, moisture, etc., should be thoroughly removed from chlorine lines during their erection. Methane derivatives, chloroform, wood alcohol, and carbon-



One of the Reducing Valves (Looking Down) on the Chlorine Feed Lines. It Is Located on the Manifold Just Beyond the Containers in the Outside Gassing Chamber

tetrachloride are the only safe chlorine equipment cleansers to employ.

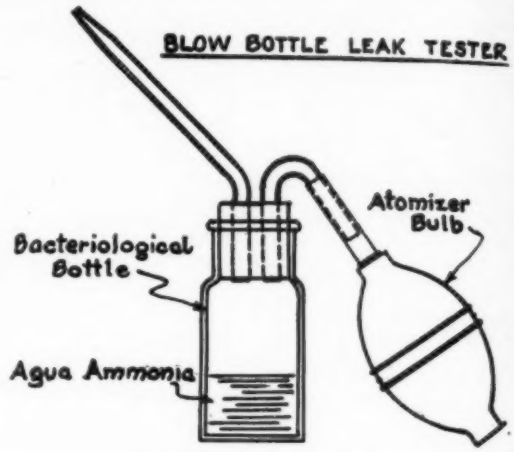
Whereas, drip legs are very helpful, condensation in chlorine lines should be avoided. If the gas leaving the container drops only a few degrees in temperature it will condense into a liquid only the feed lines and find its way into the chlorinators, with its consequent troubles. This condition can best be avoided by reducing the pressure at the containers to the lowest point permissible for the proper operation of the machines. In fact, if the line pressure be kept at 40 pounds per square inch or less no condensation can occur in the lines except at extreme cold temperatures. In Richmond, by keeping the reducing valves (in duplicate) set at 35 pounds per square inch, no liquefaction has resulted, although the chlorine feed lines are 400 feet long and the containers are in compartments outside of the plant which get quite warm in summer and also are artificially warmed in cold weather—an ideal condition for condensation in the feed lines.

Chlorine, in distilled water, at 49.2 deg. F. will form chloral-hydrate, commonly referred to as "chlorine ice." This condition is frequently found in the trays of vacuum type chlorinators during cold weather; but may be overcome by placing an electric light under the tray of the chlorinator. At the same time, reducing the water flow through the tray is also helpful. Since the solubility curve is a very sharp one a rise of only one or two degrees of the water is sufficient to do away with the trouble.

Container Temperatures and Pressures

The per cent of container volume occupied by liquid chlorine in the containers, when loaded to the limit permitted by the Interstate Commerce Commission regulations, is such that at 153.9 deg. F. the cylinder becomes completely filled due to the expansion of the liquid chlorine. Liquids do not have the compressibility or cushioning effect possessed by gases hence any further increase in the temperature will cause enormous pressure in the containers. For this reason, fusible plugs are provided which are intended to soften at slightly above this temperature and thus relieve the dangerous pressure. It is important, therefore, to keep the cylinders below this temperature regardless of the amount of chlorine that they may contain. Experience at the Richmond plant justifies this warning.

There are several practical precautions suggested by the above facts. Cylinders should never be directly heated by flame, steam or even electrical means that can exceed 160 deg. F. To avoid such hazard, warm air from the building is blown through an underground pipe to the containers which are housed in compartments outside of the plant. Secondly, a full cold chlorine cylinder has a lower pressure than one at room temperature; hence, if they are connected together as on a header, the cold cylinder will actually draw in chlorine. If the valve is then closed the overload cold cylinder may cause trouble when it becomes warm, even to room temperature. Hence, cylinders should be brought to about the same temperature before being connected together. As another example, the re-loading of containers thought to be empty, is absolutely forbidden unless under technical supervision.



The Chlorine Leak Tester

If gas is drawn from a container, the pressure within the container will be reduced. If a constant supply of gas at constant pressure is to be maintained, then heat must be applied to the liquid in the container. The more rapidly the gas is removed, the more rapidly heat must enter. This is usually accomplished by increasing the room temperature. If instead of adding heat, the container is cooled—the pressure falls. This is why a leaking cylinder should be cooled as rapidly as possible. Different opinions exist as to the maximum rate that gas may be drawn from cylinders. Experiments at Richmond have indicated that as much as 800 pounds per day may be drawn from the standard one ton container, in the summer when indoors, with pressure maintained on the gas line at not less than 30 pounds per square inch. However, 400 to 450 pounds per day is about the maximum successful continuous rate of supply from these containers. With the 150 pound cylinder the rate is about 30 pounds per day. Increasing the room temperature and providing air circulation will increase the rate of gassing. Especially so with a full cylinder because there is then a large area of the liquid exposed to the sides of the warmed cylinder. Adequate air circulation is a considerable aid in maintaining sustained gassing rates.

Handy Light Weight Safety Truck for Cylinder Handling (Courtesy Carl Leipold, Winnetka, Ill.)

Handling Containers

Containers are built of steel and may be safely handled with care. Dropping or bumping containers is extremely dangerous, and facilities used in handling should be carefully arranged to prevent such rough treatment. Hoisting is to be avoided if possible. Low, rubber tired trucks are preferable if conditions allow. A rubber tired light weight hand-truck for 150 pounds cylinders, first used by Carl Liepold at Winnetka, Ill., plant has proven both safe and convenient. The overhead monorail system used in Richmond for ton containers, involves the use of a lifting hook used to reduce space and suitable for low head operation on such a system. Out of doors storage is provided in racks, the enclosed section being the warmed gassing chamber. The maximum chlorine temperature yet found in these stored containers is 108 deg. F. or a pressure of 160 pounds which is amply safe. In warmer climates it may be well to shield stored containers from direct heat of the sun.

Chlorine may be safely stored indoors. Having the containers in operation mounted near the control machine undoubtedly has its advantages. In small installations, having in storage or in

use only a few 150 pounds cylinders, this risk is not serious and the practice is to be recommended, but when larger quantities of chlorine are necessary the advantage of the out of door storage and gassing chamber, with only the chlorine feed lines and the machines in the building, is certainly evident.

Ventilation Facilities and Leak Handling

When storage and operating containers are indoors adequate and reliable ventilation is essential. Exhaust air ducts draining air from the room should intake at the *floor level* and a fan forcing air into the room should drive the chlorine atmosphere directly out of the building. Where steam is available, a suitably designed ejector system, with discharge to a sewer or stack, is perhaps the best disposition of the escaped chlorine.

The use of neutralization tanks containing caustic, or attempting to stop a leak by spraying water on the leak, or cooling with ice and salt, while theoretically correct, are of doubtful practical value. Practically it has been found at the Richmond plant that the best disposal is by submerging the cylinder, as for example, in the raw water flume, or other convenient large body of flowing water. "Dry Ice" (solid carbon dioxide), is the only method used successfully in cooling a cylinder to stop a leak by sufficiently reducing the gas pressure.

A suitable number of gas masks, of a design approved by the U. S. Bureau of Mines, should be readily available in a convenient location, and all employes should be trained in the correct procedure in putting on the masks. There is quite a prejudice among a large number of operators against the use of a mask in stopping small leaks. Contrary to general statements otherwise, that chlorine exposures produce no cumulative effects, the writer has noted cases of men repeatedly exposing themselves to small concentrations and have ended up with irritations such as results from a heavy concentration. It is well to note that the life of a canister type gas mask of the soda lime-activated charcoal type, depends not only upon the extent to which it is put to active service, but upon the storage conditions. Such canisters deteriorate rather rapidly when left open to the air and, therefore, the bottom opening of the canister should be kept sealed with the plug or disc supplied by the manufacturer. The useful life of a canister cannot be predicted and a fresh canister should always be available. Canisters should be replaced periodically, regardless of use.

Remember three simple rules in using a gas mask:

1. Never use where there is any danger of a deficiency of oxygen.
2. The life of the canister is an unknown quantity.
3. Any gas mask job is a *two man* job.

Even small chlorine leaks are dangerous and should be stopped immediately. A chlorine leak may be readily located by means of aqua ammonia. The best procedure so far found in Richmond consists of the use of a "blow-bottle" here illustrated. This is a bottle of suitable size to carry in one hand conveniently. A rubber atomizer bulb is attached and permits the operator to blow ammonia fumes from the bottle while holding the outlet nozzle near the suspected leak. This outfit can be easily manipulated with one hand.

Flexibility of Chlorinator Service

Chlorine control machines are relatively expensive, yet ample reserve against extra demands or repairs is absolutely essential in every plant. To reduce the number of machines needed, and yet leave reliable reserve at the Richmond plant has been installed a most successful transfer system. Three points of chlorine application before filtration and four control machines are available on the transfer. By means of the transfer system, the opening of a valve permits any or all of the four chlorinators to supply any or all of the three points of application. By changing hose connections two additional control machines may be substituted thus making six machines almost immediately available at any point of chlorine application. Thus six machines give as reliable service as would ordinarily necessitate nine machines.

The author wishes to gratefully acknowledge his indebtedness for the suggestions and criticisms of: M. C. Smith, Chairman of the A. W. W. A. Committee on Chemical Hazards in Water Works; L. H. Enslow, Research Engineer of the Chlorine Institute, and Editor of WATER WORKS AND SEWERAGE, and to Carl Liepold of Winnetka, Ill.

SOLVING CHLORINE ICE TROUBLE

By DON CALDERWOOD

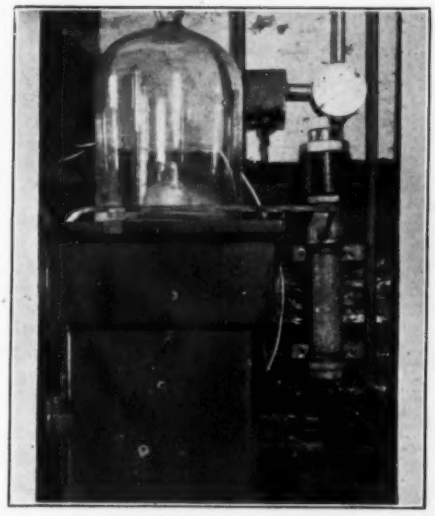
Engineer, Pennichuck Water Works Co.
Nashua, N. H.

IF you have had trouble with chlorine hydrate—usually called chlorine ice—forming in your chlorinator, you may be interested in hearing how we solved this problem.

A few years ago we purchased a Wallace & Tiernan type MCVM chlorinator. The following winter we experienced our first real trouble with so-called chlorine ice. We built a wooden box over the bell jar and put electric lights in it; we tried a unit from a sun bowl heater inside the standard under the tray; and then a combination of both. These gave results after a fashion but did not do a real workmanlike job—so after three or four seasons of makeshift operation we set out to find a permanent solution to the problem.

We purchased a 1,500 watt immersion heater with a three heat switch giving us 500, 1,000, or 1,500 watts as needed. We then took a piece of 2½ inch pipe about 10 inches long, screwed a cap on one end, a reducing coupling on the other, and into the reducing coupling we screwed the 1,500 watt heater. We next tapped into the cap and coupling for ⅛ inch copper tubing and after fastening the assembled unit to the chlorinator we disconnected the water supply line to the tray and with copper tubing made new connections so that all the water going into the tray first passed through the heating unit. To eliminate the possibility of forgetting to turn the heat either on or off, we purchased a pressure switch and connected it to the water supply line in such a way that it automatically turns the current for the heating unit on when we turn on the water supply to the chlorinator, and also turns it off when the water pressure is shut off.

This scheme worked perfectly for about three winters and then a ground started to show on our switchboard. We traced it to the heater and found that in our zeal for efficiency and in our desire to utilize all the heat available we installed the heater with the electric connections pointing down. During the humid summer weather condensation from the outside of the pipe had run down on the electric connections finally causing the ground. We have now reversed the unit, putting the heater in from the top and expect no more trouble. We find that low heat, or 500 watts, is all the current we need to use except for a few days during the coldest part of the winter.



Our First Heater

This heating unit worked so well that we decided to put one on the chlorinator in our other station even though we use that station very little in the cold weather. This chlorinator was an older model and did not have a separate valve and line for the tray water supply, so we connected the heater similar to the other installation but conveyed the warm weather from the heater directly over the top and into the tray. The water supply was adjusted so that the water flowing through the heater and into the tray was just a little less than the required amount, the remainder being supplied in the usual way through the float valve in the tray supply line.

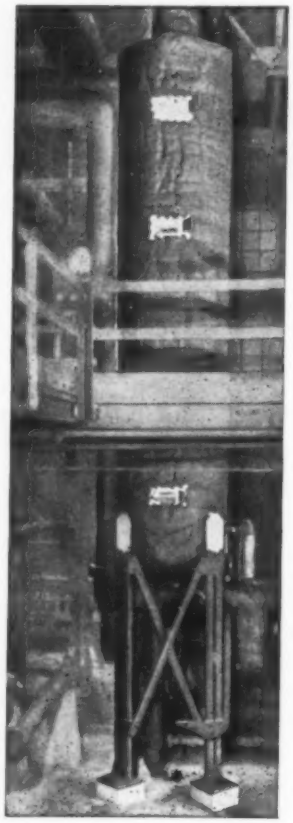
PENNSYLVANIA SALT MANUFACTURING COMPANY

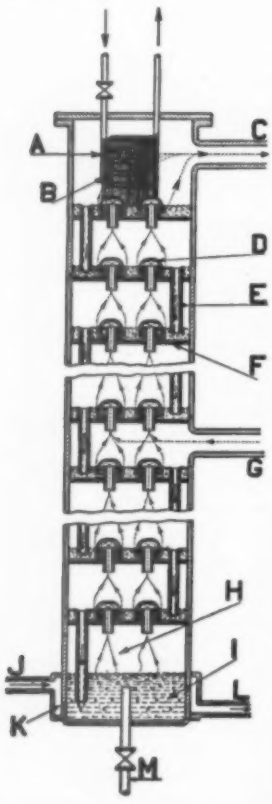
1047 WIDENER BUILDING, PHILADELPHIA, PA.

NEW YORK • CHICAGO • ST. LOUIS • PITTSBURGH • WYANDOTTE • TACOMA

• LIQUID CHLORINE

A clean amber-colored liquid about one and one-half times as heavy as water. Supplied in steel containers which are under pressure at temperatures above 30.1° F. It is only slightly soluble in water, its maximum solubility in distilled water being about 1% at 49.2° F. When pressure is released, liquid chlorine volatilizes into a greenish-yellow gas which is about two and one-half times as heavy as air. It is non-inflammable, non-explosive, and a non-conductor of electricity. Generally, in the absence of moisture it is not corrosive to common metals at temperatures below 212° F. Moist chlorine or aqueous solutions of chlorine require special equipment materials for handling.





Operating Diagram of the Chlorine Fractionating Column

A. Refrigerating Coil
B. Condensing purified chlorine
C. Purified chlorine outlet
D. Bubble cap
E. Downtake for reflux
F. Tray or plate
G. Raw chlorine inlet
H. Chloroform vapors
I. Chloroform and dissolved impurities
J. Steam inlet
K. Heating jacket
L. Condensed water
M. Drain for impurities

Chlorine has been proved to be the most efficient, flexible and economical agent for sterilizing water supplies; and it is also used as a sludge stabilizer, a taste and odor eliminator, a precipitating aid, and, in sewage treatment, for disinfection, for B.O.D. reduction and odor control. The quantity of chlorine required in water purification and sewage treatment processes depends upon the quality of water, the point of application, and the object desired. Penn Salt Liquid Chlorine is particularly adapted for such processes because of its high purity and freedom from objectionable "taffy" or chlorine gum, achieved by means of the specially designed Penn Salt fractionating column which eliminates practically all harmful impurities from the chlorine.

This Liquid Chlorine is supplied in seamless steel cylinders in sizes ranging from 10-lb. net to 150-lb. net. They comply with requirements of the Interstate Commerce Commission concerning specifications, retesting, loading, maintenance. Liquid Chlorine is also shipped in multiple-unit tank cars holding 15 containers of one ton each, and in single-unit tank cars of two sizes, 32,000 and 60,000-lb. respectively. The care with which all Pennsylvania Salt packages are cleaned and double-checked, coupled with the quality of Penn Salt Liquid Chlorine, assure maximum safety and convenience in chlorinator operation.

• PERCHLORON

Per*chloro*n is a high strength calcium hypochlorite, having a guaranteed active ingredient of not less than 70% calcium hypochlorite or available chlorine. It is free flowing, concentrated and retains its labeled strength for one year or more under normal storage conditions. It weighs approximately 52.5 pounds per cubic foot. It is composed of finely divided particles, all of which will pass a 20 mesh screen and be retained on a 65 mesh screen. It is quickly soluble in water, and is useful as a second line of defense for water purification in cases of emergency, when supplies of liquid chlorine may be temporarily cut off. Per*chloro*n is also used for sterilizing new mains, as well as clear wells and filters; valuable for sewage treatment, too. Many leading swimming pools sanitize their water with Per*chloro*n, use it to combat slime and algae growths, and to control athlete's foot by means of trays and spraying locker and washrooms. Per*chloro*n is supplied in handy-sized cans equipped with Kork-N-Seal covers, 9—5-lb. cans to the case. Also in 100-lb. drums.

• AMMONIA, Anhydrous

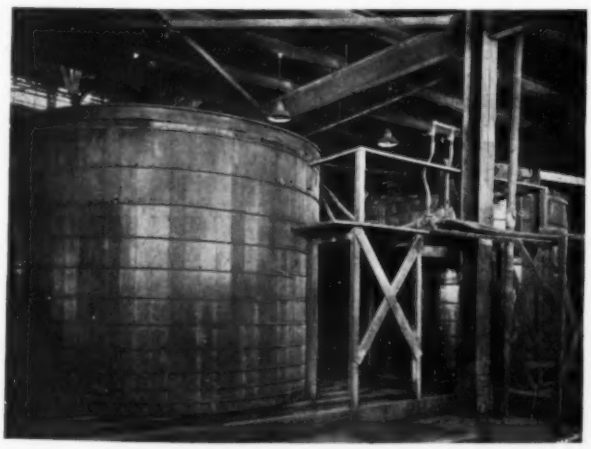
A colorless liquid which at 70° F. is 0.61 times as heavy as water, and weighs 38.0 lb. per cubic foot. When pressure is released, it volatilizes to a colorless gas of penetrating odor, which is 0.597 times as heavy as air at standard conditions. Dry ammonia is not corrosive to the common metals, but moist ammonia attacks copper and all its alloys, hence iron pipe and fittings are always recommended. Ammonia is exceedingly soluble in water. At 32° F., 1150 volumes of ammonia will dissolve in 1 volume of water, or 47.3% by weight.

This characteristic of ammonia is utilized in the dry feed ammoniators in water works. It is also useful in the chloramine process, in which ammonia is applied along with chlorine to prevent the formation of chlorinous, phenolic or medicinal tastes; and for stabilizing or prolonging the sterilizing action of chlorine. Ratios of ammonia to chlorine varying from 1:1 to 1:12 have been effective, with points of application ranging over the entire purification process. To prevent taste intensification, the ammonia must be applied before the chlorine.

Pennsylvania Salt Anhydrous Ammonia is supplied in special improved cylinders of seamless drawn steel which are light, strong and easy to handle and store. Gas may be withdrawn either with a cylinder standing upright on a scale for weighing, or with the cylinder lying horizontal, whichever is most convenient.

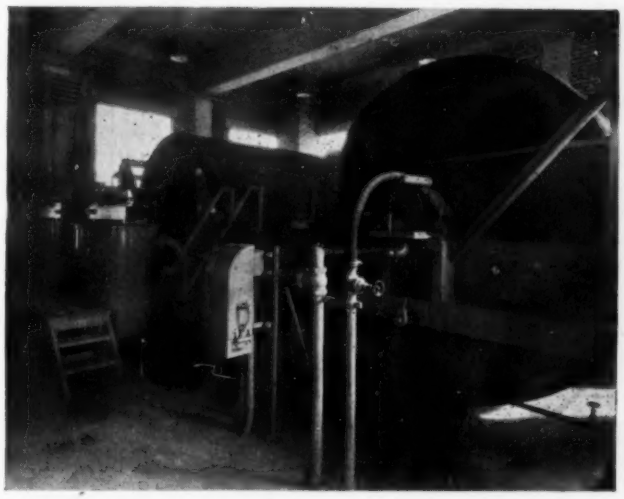
• FILTER ALUM (Sulphate of Alumina)

This product is the principal coagulant used in water purification; and Penn Salt Filter Alum has been adopted by many water works superintendents and engineers. Available in any quantity from a single bag or barrel to carload lots. Bags and barrels are paper lined as a protection against atmospheric moisture.



• FERRIC CHLORIDE

In liquid form it is an aqueous solution, the concentration of which is governed by the outside temperature and varies from 39% $FeCl_3$ in extremely cold weather to 45% in extremely hot weather. Pennsylvania Salt also supplies ferric chloride in an anhydrous form which is water-free and as near to 100% $FeCl_3$ as is permitted by impurities in the steel scrap from which it is made. Ferric chloride is a positive coagulant, producing clean-cut flocculation in economical doses. In most communities, depending upon shipping costs, ferric chloride offers vast savings over alum. The aqueous solution is shipped in rubber-lined tank cars holding 8,000 gallons and averaging 40,000 lb. of dissolved $FeCl_3$ per car. Anhydrous ferric chloride is shipped in non-returnable steel drums, 150 and 400 lb. sizes.



• SODIUM ALUMINATE

An alkaline compound of alumina and caustic soda, used both for softening water and as a combined coagulant and softener. Most effective in water requiring an alkali with the alum. Shipped in thin steel non-returnable drums, net weight 100 and 400 lb. each; and in 100-lb. moisture-proof burlap bags.

• SODA ASH
CHLORIDE OF LIME, and
CAUSTIC SODA

are among the other chemicals made by Pennsylvania Salt and used in water purification and sewage treatment. Ask us for detailed information and expert technical assistance.

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Ammonia Control Apparatus, Dry Chemical Feed Devices, Etc.

NEWARK, N. J.

"The Only Safe Water Is a Sterilized Water"

REPRESENTED IN

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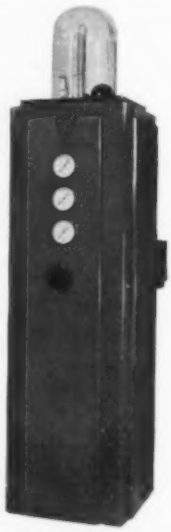
REPRESENTATIVES IN FOREIGN COUNTRIES

CHLORINATION FOR SAFETY

W&T Chlorination Trailer for self-powered protection in the case of emergencies requiring chlorination at any point in the system.

Continuous treatment by chlorine is the one method now almost universally used for protecting public water supplies from disease bacteria. Wallace & Tiernan equipment for this purpose safeguards over 85% of America's public water supply. For permanent installations, W&T "Visible Vacuum" Chlorinators furnish closely controlled solution feed over a wide capacity range, with either manual or automatic regulation of the application rate. For small water supplies, W&T Hypochlorinators assure safety with simplicity and low cost.

For emergency use, the Wallace & Tiernan Chlorination Trailer is self-powered. Designed for use at any point in the water system, this unit is particularly applicable to main sterilization, secondary chlorination of open reservoirs, in case of pollution from cross connections, in fact wherever and whenever chlorination may be required. Also available for use at any point in the system is the new W&T Portable Chlorinator which provides for compensated solution feed. Both of these units have been designed in accordance with information on English experience, as well as consultation with American military and civilian defense authorities.



W&T "Visible Vacuum" Chlorinator for automatic proportioning of chlorine to the flow of water. A companion unit with manual control is also available.

HYPOCHLORINATOR

Some chemicals, such as hypochlorites, are available in stable solution and present problems in dry feed which make it most desirable to apply them in solution form. The W&T Hypochlorinator is designed to feed such solutions as sterilizing agents, coagulants or corrosion inhibitors with accuracy and dependability.

TASTE AND ODOR CONTROL

Modern water treatment methods such as "breakpoint" chlorination and chlorine-ammonia (chloramine) treatment not only raise health protection standards but act to overcome taste and odor troubles due to algae, industrial wastes, and the like, thus furnishing a water that is more palatable as well as completely safe.

APPLICATION OF DRY CHEMICALS

Wallace & Tiernan produces several types of dry chemical feeders for uniform, wide-range feed of such powdered chemicals as alum, lime, soda ash, carbon, etc. This dry chemical application has become particularly valuable, and is used extensively, in both sanitary and industrial water works.

W&T MOF Dry Chemical Feeder provides wide-range feed of various powdered chemicals.

W&T TECHNICAL SERVICE

For any water treatment problem Wallace & Tiernan representatives can provide competent technical assistance. These representatives will be glad to review your problem and make recommendations without obligation.

HELPFUL FREE BULLETINS

W&T Hypochlorinator for treatment of small water supplies is economical and simple to operate.

W&T Technical bulletins give complete specifications on each type of W&T equipment.

Also available is current literature on the many phases of chlorination, ammoniation and dry or solution feed of chemicals

PART 7

SEWAGE TREATMENT

WATER WORKS
& SEWERAGE

REFERENCE & DATA SECTION

1943

% PROPORTIONEERS, Inc. %

"CHEMICAL-FEEDER HEADQUARTERS"

9 NO. CODDING STREET, PROVIDENCE, R. I.

Representatives in Principal Cities

Raw Sewage Conditioning Using Ferric Chloride and Lime can be controlled in proportion to variable flows thru the Venturi Tube, or over a Weir, measuring the influent. Ferr-O-Feeder (Fig. 1) can handle concentrated 43% ferric chloride or any dilutions; also ferrous salts and practically any other chemicals needed in sewage plants.

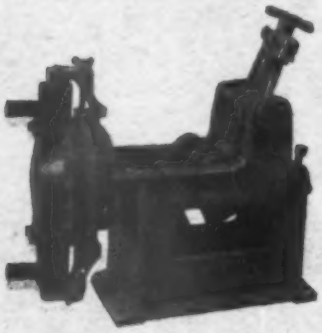


Fig. 1—Standard Ferr-O-Feeder

Sludge Dewatering — Sludge dewatering plants using vacuum filters, must automatically control coagulant administered. A Ferr-O-Feeder, used as an adjunct to the vacuum filter, measures ferric chloride and delivers it under pressure to proper point of application in mixing chamber. Ferr-O-Feeder not only accurately measures corrosive liquids but, due to positive displacement method, can deliver the chemical remotely to upper floors of the plant—wherever the filters and dewatering equipment may be located. This eliminates the need of additional rubber lined pumps for lifting or moving ferric chloride from storage to point of use. Ferr-O-Feeder is controlled by cross connection to sewage pumps; to drive motors of vacuum filters; or by belt chain and sprocket connection to bucket elevators (see Fig. 2).

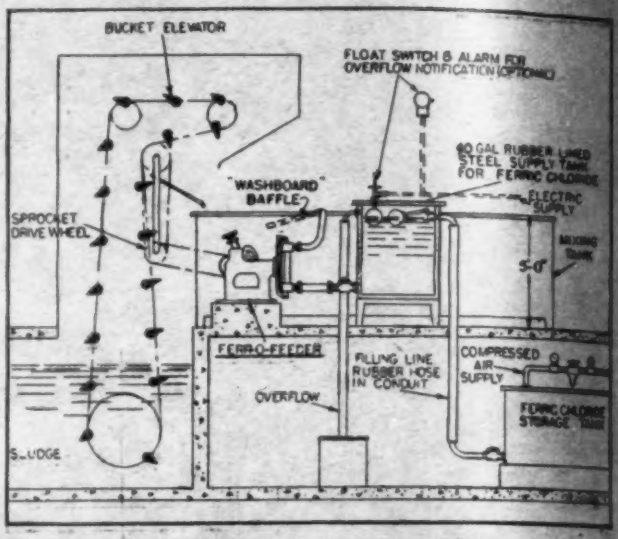


Fig. 2—Installation Diagram Ferric Chloride Feeder Controlled by Bucket Elevator

Multi-Control Feeders—Multiple feeding of several chemicals has been standardized so that 2, 3, 4, or more synchronized feeders, "ganged" on one drive mechanism (Fig. 3), can be ordered from stock.

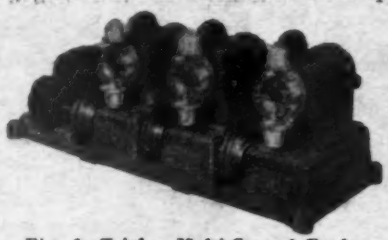


Fig. 3—Triplex Multi-Control Feeder

Heavy Duty Midget Chlor-O-Feeder Package—(Fig. 4)—This unit prevents stream pollution . . . and provides odor abatement. It is available to war plants, air bases, army camps, naval bases and municipalities on suitable priority rating.

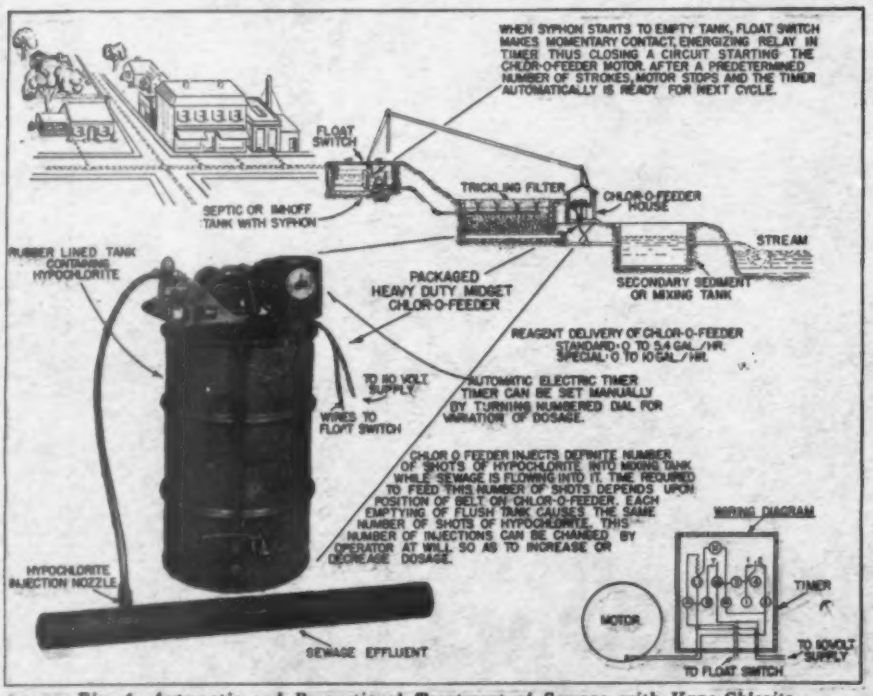

WHEN SYPHON STARTS TO EMPTY TANK, FLOAT SWITCH MAKES MOMENTARY CONTACT, ENERGIZING RELAY IN TIMER THUS CLOSING A CIRCUIT STARTING THE CHLOR-O-FEEDER MOTOR. AFTER A PREDETERMINED NUMBER OF STROKES, MOTOR STOPS AND THE TIMER AUTOMATICALLY IS READY FOR NEXT CYCLE.
FLOAT SWITCH
TRICKLING FILTER
CHLOR-O-FEEDER HOUSE
SEPTIC OR IMHOFF TANK WITH SYPHON
STREAM
RUBBER LINED TANK CONTAINING HYPOCHLORITE
PACKAGED HEAVY DUTY MIDGET CHLOR-O-FEEDER
SECONDARY SEDIMENT OR MIXING TANK
REAGENT DELIVERY OF CHLOR-O-FEEDER STANDARD: 0 TO 5.4 GAL./HR. SPECIAL: 0 TO 10 GAL./HR.
TO 60 VOLT SUPPLY
AUTOMATIC ELECTRIC TIMER. TIMER CAN BE SET MANUALLY BY TURNING NUMBERED DIAL FOR VARIATION OF DOSAGE.
WIRES TO FLOAT SWITCH
CHLOR O FEEDER INJECTS DEFINITE NUMBER OF SHOTS OF HYPOCHLORITE INTO MIXING TANK WHILE SEWAGE IS FLOWING INTO IT. TIME REQUIRED TO FEED THIS NUMBER OF SHOTS DEPENDS UPON POSITION OF BELT ON CHLOR-O-FEEDER. EACH EMPTYING OF FLUSH TANK CAUSES THE SAME NUMBER OF SHOTS OF HYPOCHLORITE. THIS NUMBER OF INJECTIONS CAN BE CHANGED BY OPERATOR AT WILL SO AS TO INCREASE OR DECREASE DOSAGE.
WIRING DIAGRAM
HYPOCHLORITE INJECTION NOZZLE
TIMER
MOTOR
SEWAGE EFFLUENT
TO 60 VOLT SUPPLY
TO FLOAT SWITCH

Fig. 4—Automatic and Proportional Treatment of Sewage with Hypo-Chlorite

Operated by remote control from Septic or Imhoff Tank with syphon, chlorinator **automatically** doses sewage as it passes from trickling filter to secondary sediment or mixing tank before final discharge to stream or river. As syphon starts to empty tank, a float switch makes momentary contact,, energizing relay in timer, thus closing a circuit, starting the Chlor-O-Feeder motor. After a predetermined number of strokes, motor stops and the timer automatically is ready for next cycle.

The %Proportioneers% Chlor-O-Feeder injects a definite number of shots of hypochlorite into mixing tank while sewage is flowing into it, the time required for these injections depending upon position of belt on Chlor-O-Feeder. Each emptying of flush tank causes the same number of shots of hypochlorite. The number of these injections can be changed at will by operator so as to increase or decrease dosage.

While this section contains material devoted exclusively to Sewerage, the reader will find additional material in the Water Works Section which also applies to Sewerage.

SEWER MAINTENANCE

By C. GEORGE ANDERSEN

Superintendent, Department of Sewers and Sewage Disposal

Rockville Centre, Long Island

In the sewerage problems of today the treatment plant and types and design of sewers seem to take the lead. Now, when one considers the investment in sewer lines as the primary structure, providing an indispensable service in the removal and disposal of sewage, we are in general too negligent in the matter of maintenance and operation of sewers for the best interests of the public and efficient functioning of the treatment plant.

At Rockville Centre the writer, like many other men in charge of sewerage systems and sewage treatment, had his problems. The first was the effective and economical treatment of liquid and solids at the treatment works. Then, after catching up on this important phase of the cycle, in looking around it seemed important to face squarely the other sewerage investment amounting to four times as much,—namely, the sewers. In Rockville Centre we have not so many miles of sewers, nor very large ones, but those we have are as important to proper functioning of the entire system as though they were in a metropolis. The sizes range from 8 to 30 inches, and these sewers clog with roots, sand and many other materials.

Sewer Cleaning

Sewer cleaning being one of our problems, after our sewer lines are laid it becomes a necessity to maintain them in good working condition, and we might just as well lay out a program of routine cleaning and maintenance, rather than wait until trouble overtakes us. Continuing and repeated emergency calls, growing out of sewer stoppages, is very costly. In addition to extra expense there results many disgruntled taxpayers, inconvenienced by stoppages and put to added expense, due to their sewer lateral being plugged because of some backage in the main in the street.

Some Notes on Equipment and Its Effectiveness

For sewer cleaning and removal of roots, there are many types of equipment now available. Flexible steel sewer rods are a recent innovation in such equipment. These rods have an advantage in that the necessity for going down in manholes is eliminated. The rods are made up in three foot lengths, which coupled together make one complete flexible rod that is usually coiled between uses. Wood rods of five foot lengths (coupled together as they are being pushed into the sewer line) also continue in use to some extent. The wood rods, being more rigid than the steel rods, follow a straight line more successfully, but cannot be turned and forced to the extent that the new flexible steel rods can.

The "Turbine" type of sewer cleaning instrument is probably the most positive of all types made today. This device (adjustable to any diameter sewer) is a water powered rotating cutter. In employing the "Turbine", it is necessary to have two winches and cable to draw it through and back between manholes in the line, while the high speed rotating knife blades do a clean job of root cutting and scaping.

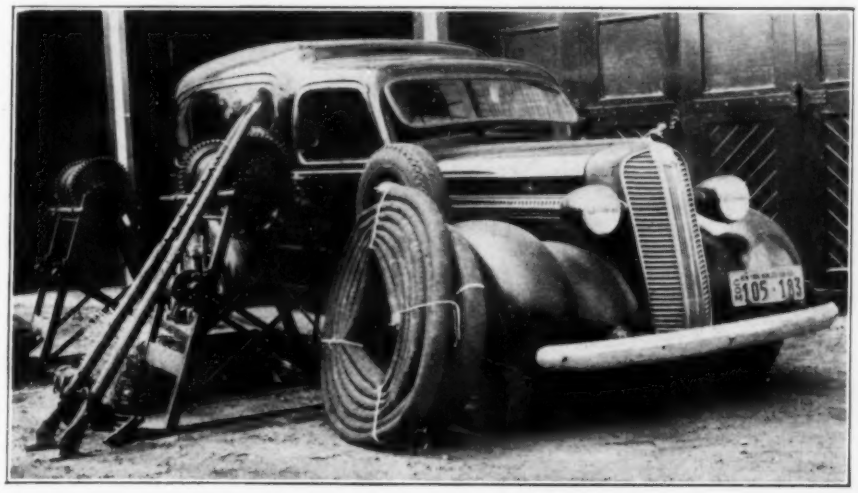
Rods of any kind, which can be used efficiently in making time and mileage when going over an entire sewer system as laid out in a program, are good up to a certain point such as the removal of small deposits and light root growths. On the tougher jobs, such as spots where knob roots have formed (see cut), a more positive applied type of equipment is required. In such cases it becomes necessary to use the "Turbine" cutter, or some similar tool, that will slowly but surely remove the obstruction if it is such as can be cut by steel.

I stress this point, because on one occasion a severe stoppage occurred in an eight inch line. Our Flexible sewer rods were first used, but could only give relief to the extent of four inches. That is, the four inch auger-head was the largest tool that could be forced through. The supposition in this case was that the trouble was caused by a broken spur, being replaced by a makeshift stack which extended into the sewer line. Many other suppositions also were expressed, but there is only one thing to do in a case like this (and such is good for experience)—dig it up. This was done and the trouble was, in fact, at a spur. The spur was not at fault, however, but through the joint preceding it a large root had entered. The question was, how to remove it. A hole was cut in the eight inch tile sewer line so that action of the available cutting tools could be observed as it was applied to the root. The root had formed a five finger knob on the top inside of the pipe (see cut). When the Flexible sewer rod with the auger used in eight inch line was applied to the root the tool just jumped back and had no effect. This satisfied me as to the necessity of having a positive applied sewer cleaning cutter, especially for clearing out those very deceiving *top* roots which cannot be removed by auger and do not stop sewage flow until they are definitely a menace in the sewer.

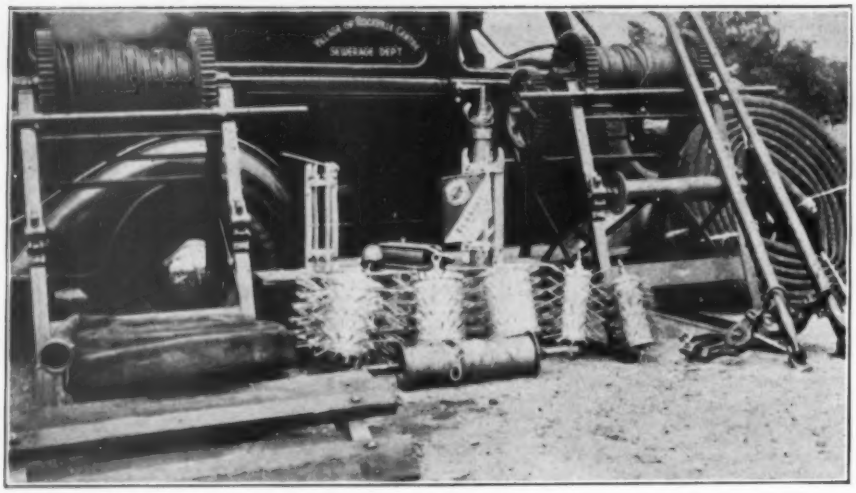
Sand and gravel which have built up around paper, roots and other matter in a sewer, are also a headache. We find that one cannot have *too much* equipment. And, we have also learned that in sewer maintenance different makes of equipment can be used in combination or in sequence to produce very efficient work. Take the case of sand; Flexible steel rods can be used to get an opening through the sand. This constitutes the first important step. Then a cable may be drawn through so as to draw a bullet or tool for loosening and liquifying sand stoppage. Thereafter, the Turbine flusher or cleaning buckets, whichever proves the more efficient, may be used.

Mapping and Program Setting

In setting up our maintenance program, the village map was taken and divided into sections, each section being given a number. In connection with the map, a section book, card index and a daily log book was also established. The section-book is made up of all the sewer sections, showing the sewer lines flush manholes, distances between manholes, etc. Each page (map) covers a separate section (see cut) and the crew operating makes constant use of detail maps in the field. The card index is set up



Our Maintenance Truck and Equipment
A 1½-ton unit, which seems a little light. A 2½-ton unit we believe preferable.



Some of the Equipment

Hose and guards in left foreground; a pair of cable winches, against one which leans cable braces with pulleys inserted in manholes to guide cables. In center, a spool of light threading cable and a set of effective metal scouring brushes (8 to 18 in) supplied by the Turbine Company of Milwaukee. Rear center, on chest containing cutting tools and sleds (6 to 20 in.) for Turbine Cutting heads, is a drag and Turbine Cutter complete for 8 inch jobs.

for each section and any conditions found worth remembering for the future is recorded on such cards. The log book maintained to show a complete record of all work done in connection with maintenance and cleaning, carries daily reports showing the number and location of the work section, the type of equipment found needed, number of feet of sewer cleaned, remarks on conditions, number of laborers employed and cost of the job for the day. A specimen page from the current log-book is here reproduced to better picture the type of entries made.

The plan of maintenance is so arranged that at least 78 miles of sewer will be checked once every three years or 26 miles yearly. The actual working time is 5 days per week during the spring and summer months only, involving in all about 150 days per year of maintenance work. The program is planned and timed to run from March 15 to July 1st, the work being resumed in September and terminated on November 15th. The reason for such a schedule is that it eliminates this type of work in the hot weather and also in the cold winter season, the two most disagreeable times to do this work in an efficient manner at least cost.

In the program the business area is done during the month of June, work commencing at 4 A. M. and stopping at noon. At this time of the day there is the minimum of traffic of any kind to hinder the work, therefore all work that is interfered with by traffic can be completed by the time traffic does start to move The three man operating crew consists of a leader, who must be a reliable, industrious individual, and two day laborers. A sewer inspector (or the superintendent) orders sections of work to be done, and likewise supervises the work and sees that adequate records are kept.

In connection with organization, consideration must be given to equipment mentioned and a transport for such. The truck does not have to be an unsightly thing. We use a 1½-ton black panel job, but find that a 2½-ton unit is preferable, as more space is available for the equipment, which consists of 1000 feet of hose. manhole and hose guards, Flexible rods and cutting tools, water powered Turbine, cutter, shovels, picks, lantern, flags, tools and emergency first aid.

The operation of the maintenance crew is to put through the sewers a tool that will either indicate a clean sewer, or remove stoppage, or determine the necessity for a more detailed job such as "turbining." In their travels they repair masonry in manholes, pack loose manhole lids that disturb residents because of banging under traffic.

In stopping rattling manhole lids many things were used which were unsightly on the streets. A gum was then used and served the purpose for a time. The most satisfactory thing to date has been a tape packing called "Tapax." It is laid around the full circumference of the manhole lid seat, after thoroughly scraping and brushing it clean.

In the larger sewers (15 inch and above) we find that the large wire brushes, that are part of our "Turbine" line of equipment, can be used more efficiently for cleaning and indicating trouble than can the Flexible steel sewer rods.

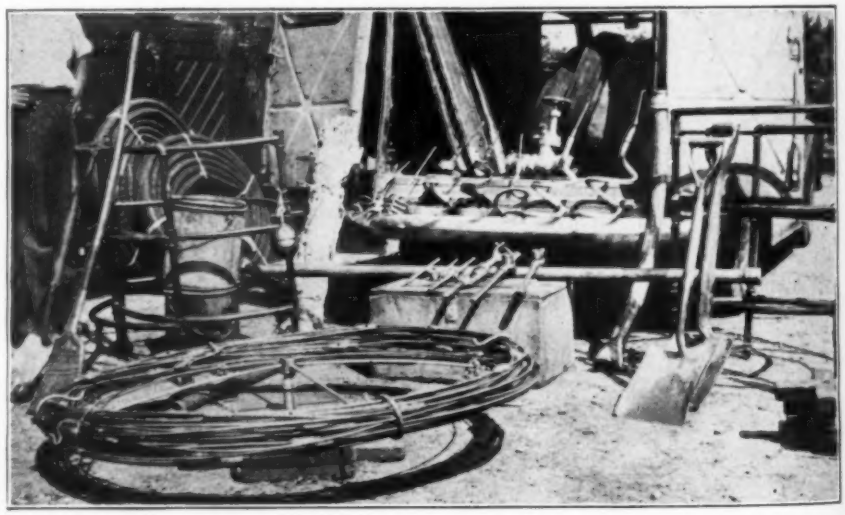
The mere looking down at the flowing sewage, after flushing, does not indicate a clean free-flowing sewer. This much the experience related previously herein has taught us.

Flushing

The basic requirements for effective flushing of sewers are splendidly presnted by J. D. Watson in WATER WORKS AND SEWERAGE for August, 1937. [The same article being reprinted in the Reference and Data Section for 1939.—ED.]

Sewers today are flushed both manually and automatically. The former method is done by using a hose or drawing from pond into the end manhole of a section of sewer line, known as a flush manhole. Also there is the automatic flush equipment frequently installed at the end of a line. The equipment includes a siphon arrangement built into the manhole and discharging into the sewer. The flush tank is continuously refilled by a constant regulated flow of water into it, the rate being controlled by a special faucet. In operation, the flush tank is filled to a certain depth by the water from the faucet. When the head of water is sufficient to cause the siphon to start operation, the siphon empties the tank rapidly and thus flushes the sewer. The idea in all cases of flushing, be it drawn from a pond, by hose, or automatic flush tank, is to cause the flowing off of sewage solids depositing in a flat grade or "lazy" sewer. The hose flushing is the most practical and effective method, as it can be applied anywhere along the line.

The automatic flush, which is still being used, has to be main-



Rear of Truck—More Equipment

Flexible sewer rods connected and coiled on revolving wheel stand. Rear of truck, replacement rods and various types and sizes of augers and screw heads (4 to 10 in.) for Flexible rod work; stop valve for controlling pressure from hydrants used in flushing and Turbine operations; Flexible rod man-hole guides, wrenches and ratchets; man-hole guards flag-stands, etc.

tained. The strainer and orifice through which the water flows to the tank has to be kept clear. Varying pressures in the water main has a tendency to loosen iron deposits which choke the strainer or orifice; also water that has been treated with lime and chlorine causes clogging and trouble with such equipment. There is also the cross connection hazard with this type of equipment which is now being eliminated as much as possible.

As mentioned before, a flow of water will not indicate a clean sewer. Unless properly applied water flow alone will not clean a sewer from a practical man's point of view, other than to flush through material that has been scraped and cut loose or those deposits that are rather easily moved. To clean a sewer effectively involves the removal of films that are building up to a thickness. To accomplish this, the positive scouring type of jetting nozzles must be run through the entire sewer. The flow from a fire plug may seem terrific on entering the line, but very soon levels out to nothing more than a fast flowing stream. As to how much it removes from the walls of the pipes is speculative.

Roots and Service Connections

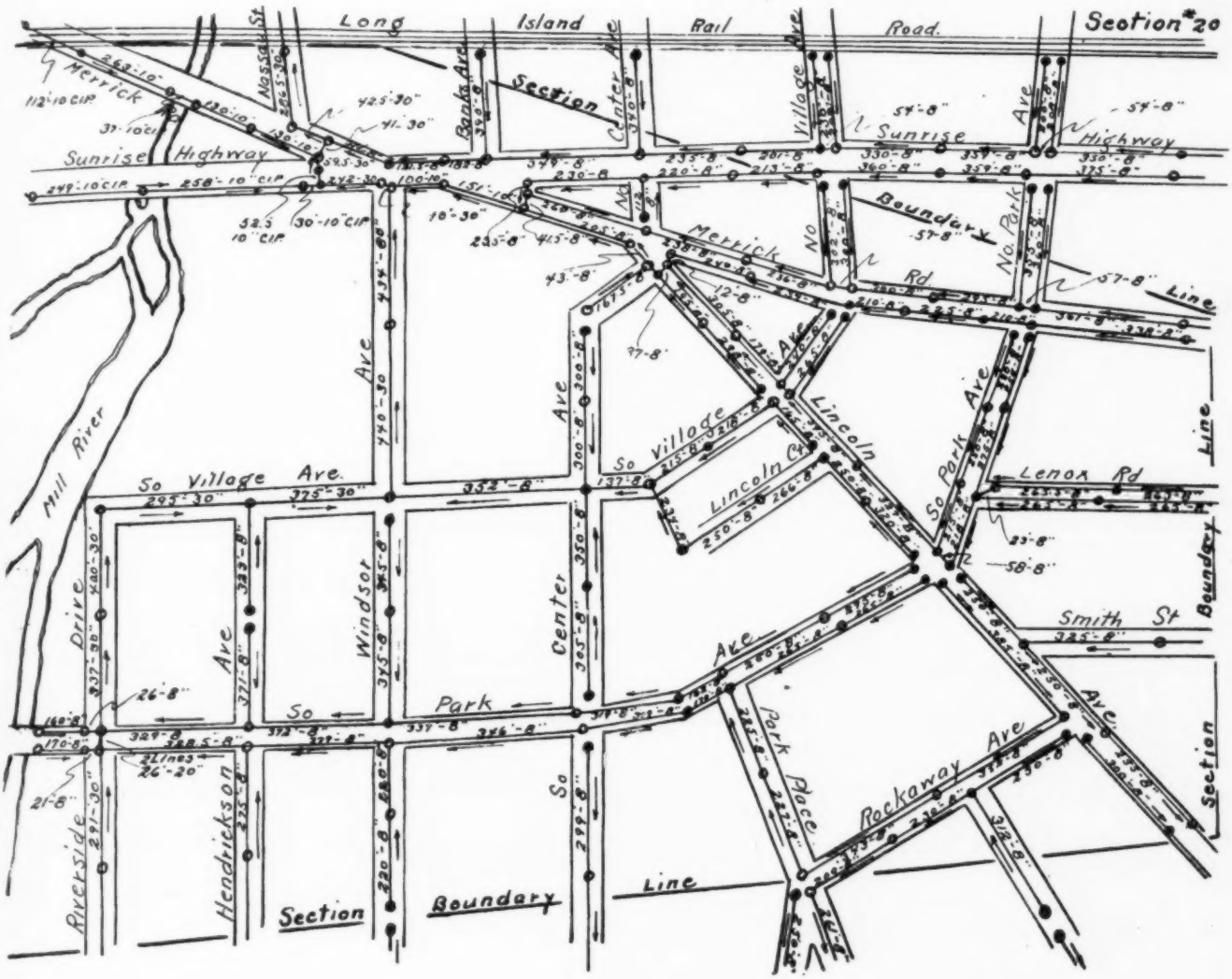
Roots are the big problem in sewer maintenance. We know where they come from—but how to control them? We can to some extent cut down the trouble in the following:

1. Stricter inspection of new lines being laid.
2. Material used for joints. This is no better than workmanship of labor performing the job.
3. Ordinance directed to elimination of the most prolific root growing trees such as poplars, swamp maples, weeping willows, etc.

It has been interesting to hear some of the reports as to how roots will be attracted to sewage, passing up water directly under them and reaching out for a crevice or bad joint in a sewer line. There are many contributing factors—the temperature of sewage, and its content of plant food being the more important.

Service connections into sewers should be inspected as to grade and workmanship of a joint. A poor grade and joint means future trouble for all concerned,—user and Sewer Department. It is so easy to take drain-layer's and plumbers' word for the work done, but once inspected and passed the installation becomes the responsibility of the department passing it. You may argue the point later and think that you have won out, but the taxpayer finally has his day, as we have witnessed so much of late.

The responsibility for maintenance of sewer connections results in a dispute many times. I contend and carry out the policy that where service charges are not made, a sewer lateral should be the sole headache of the one using it. The sewage and waste that is run out to the sewer comes from that property. Any trees in the vicinity are for his comfort, and for a department to take over responsibility from the curb to the main leaves us with the question, Where is the end? Most Sewer Departments have a limited personnel, and to be called out on each house stoppage occurring certainly makes a condition of despair many a time, because of the inability to catch up or demand more labor, which cannot



Detail Map—Section No. 20—Business District
Taken from our Section Map Book covering the 24 sections of the Rockville Center System—Practically indispensable in effective and economical maintenance work, recording, trouble finding, etc.

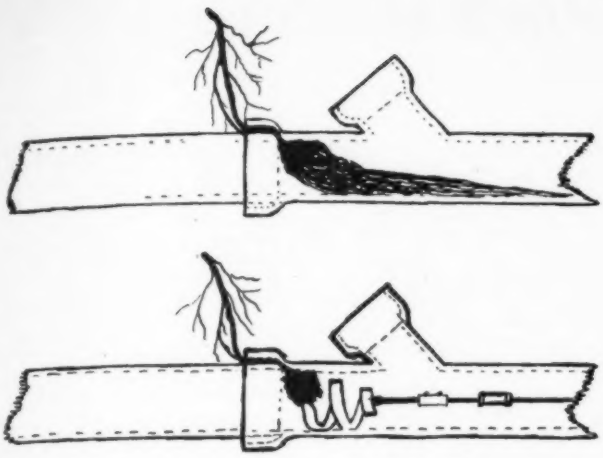
MAINTENANCE RECORD

RECORD OF ALL WORK DONE PERTAINING TO MAINTENANCE OF SEWERS

DATE	LOCATION OF WORK	SECTION	TYPE OF WORK DONE: FLEX. RODS	TURBINE CUTTER	FLUSHED	TOTAL FEET CLEANED	MISCELLANEOUS	REMARKS	NO. OF MEN	NO. OF HRS.	COST
4/4/39	So.Park Ave. bet.Lincoln Ave and Center Ave. S/S	20	X		X	489'		Found bad root condition	3	8	
4/5/39	S/S Lakeview west of Greenway St.	1	X		X	180'	On Complaint	Found break in line about 3' from 1st. d.s.m.h. that filtered water & sand into sewer	3	8	
4/11/39	S/S Park Ave bet.Center Ave and Riverside Drive	20	X		X	1053'		Bad root condition.	3	8	
4/11/39	N/S Park Ave.bet.Riverside Dr. and Center Ave.	20	X		X	1038'		Root condition - not bad	3	8	
4/12/39	N/S Park Ave.bet.Center Ave. and Lincoln Ave.	20	X		X	731'		Bad root condition	3	8	
4/12/39	E/S So.Village Ave.bet.Lincoln and Merrick Road	20	X		X	265'	On Complaint	Found roots in this line, no trees within 150' of stoppage	3	8	
4/13/39	N/S Park Ave.bet Center Ave. and Lincoln	20	X		X	275'		Bad root condition	3	8	
4/14/39	Center Ave.bet.Park Ave and Shellbank	20	X		X	869'		Bad root condition - broke several rods	3	8	
4/14/39	Windsor Ave.bet.Park Ave & flush manhole So. of Park	20	X		X	440'		Some roots - not bad enough to give trouble	3	8	
4/17/39	Windsor Ave. So. from flush manhole to Shellbank Place	19	X		X	440'		Light roots	3	8	
4/17/39	S/S Lakeview Ave West about 350' from Hempstead Ave	9	X		X	320'	Demonstration	New Sewer Cleaning tools used	3	8	
4/18/39	Hendrickson Ave. from Park Ave so. to Shellbank Place	20	X		X	980'		Bad root condition	3	8	
4/18/39	Hendrickson Ave from F.M.H. No. to So.Village Ave	20	X		X	323'		Very bad root condition	3	8	
4/19/39	Hendrickson Ave from F.M.H. So. to Park Ave.	20	X		X	371'		Very heavy roots	3	8	
4/19/39	Windsor Ave. from So. Village to a point half way to Park	20	X		X	345'		Very heavy roots	3	8	
4/20/39	Windsor Ave from a point half way bet.Village, Park to Park	20	X		X	345'		Root condition - not bad	3	8	
4/20/39	Center Ave. from Park Ave to Village Ave.	20	X		X	655'		Bad root condition	3	8	
4/21/39	Lincoln Ave. W/S from Lincoln Court to So. Village Ave	20	X		X	165'		Light roots	3	8	
4/21/39	So.Village Ave. from Lincoln Ave. down to Windsor	20	X		X	922'		Heavy root growth bet Lincoln Ave & Center Ave line partly clogged with sand	3	8	
4/24/39	W/S Lincoln Ave from So.Park to Lincoln Court	20	X		X	470'		Light roots-line very sluggish	3	8	
4/24/39	Lincoln Ct. from Lincoln Ave to P.R.W. to So. Village Ave	20	X		X	750'		Light roots-Lincoln Ct..Sewer opposite Lincoln Inn, filled with grease	3	8	
4/25/39	Center Ave. from So.Village to Merrick Road	20	X		X	767'		Light roots near Merrick Road	3	8	
4/25/39	Lincoln Ave. W/S from Merrick Rd. to So.Village Ave.	20	X		X	558'		Heavy root growth near Petitts Bros.	3	8	

SUPERVISION AND LABOR @ 25.00 PER OPERATING DAY - ENGINEERING DIVISION - PLANNING & ESTIMATING

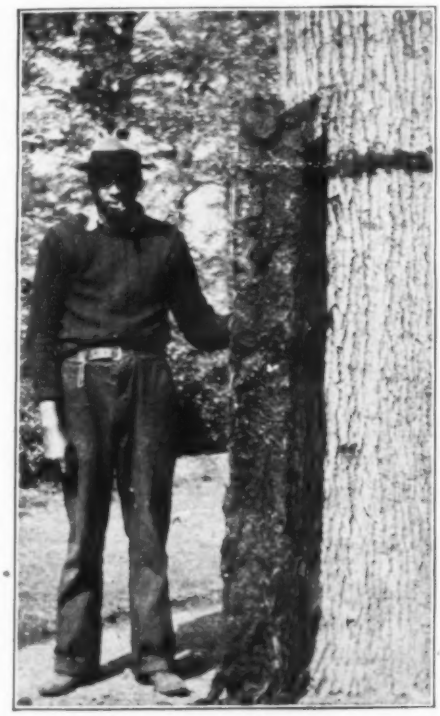
Page from Maintenance and Repair Log Book, Revealing Records Kept



Type of Top Root and Knob Which Calls for a Positive Cutter Here the water pressure driven cutter does the job.—See Text.

always be justified. The use of castiron house connections will eliminate much grief for all concerned.

The policy as to sewer connections lays with a governing body of a community, and it is the duty of an officer of a department to bring forcibly, and with clarity, any constructive measures that he recommends. If this is done, he has done his duty to himself and the taxpayer. It is his duty then to carry on to the best of his ability.



One of Our Pets

A prize root which tore away, leaving a five-finger knob on the top inside of pipe —see sketch—which was still a stoppage producer.

Pump Stations

The pump station is the central point to which all gravity lines feed, and it puts us in mind of a large city into which everything pours and straggles, and with positive energy must clear itself to survive. And so in our pump stations, consideration must be given to what comes in and to what extent we must go to dispose of it. The very mention of a pump station brings to us the fact that there is equipment to be considered. Screens, be they bars or baskets or mechanical grinders, have to be kept clean and the mechanism has to be checked regularly for lubrication, wear and tear. Pump and motors should be inspected regularly as to alignment, lubrication—changing old oil and grease at least once a year. Check pumps for clogging, also condition of packing. Pumps should be taken down at least once every five years, if they have run that long without trouble. In that way parts may be replaced at your pleasure and not at some inconvenient time, as an emergency. The conditions under which a pump works more or less determines the time for inspections.

Chlorinating equipment should be inspected for leaking joints; exposed parts should be covered with vaseline; strainers and other parts that clog with salts should be inspected as often as necessary. Under ordinary conditions once every three months is sufficient. Chlorine causes considerable trouble to electrical equipment and the two should never meet. Newly designed stations have a complete separation of the chlorine room from other parts of the building.

The well into which all the sewage flows should be kept clean for at this point sludge and grit settle out and putrifaction and odors set up which become a nuisance to surrounding properties. Daily flushing of a well is the most efficient way of keeping it clean. Any solids or grit which have settled can easily be flushed away with an inch and a half hose and nozzle. While considering the adjacent property owners, it is well to consider the beautification of the grounds and maintenance of the inside and outside of the building. The care of pump stations, if there are enough of them, warrants a utility man whose job it is to keep them in condition.

Costs

The cost of this type of maintenance shows an excellent economy in the form of a satisfied public, and also in dollars and cents. The equipment needed for effective maintenance totals some $2,700, and we plan on replacement every three years. Depreciation and interest runs the equipment cost to about $900 per year for our system. To this must be added $25 per day for 150 days per year to cover planning, administration, supervision, labor—say $3,750 per year.

Based on a coverage of 26 miles (137,280 feet) the cost per foot of sewers cleaned and maintained is—

$$\frac{(150 \text{ days} \times \$25) + \$900}{137{,}280 \text{ ft.}} = \$0.34 \text{ per foot.}$$

To cover liability, other insurance, and miscellaneous items such as gasoline, water used, etc. The cost may run to 4 cents per foot maximum.

Summing Up

The old method of sewer maintenance, which usually amounted to keeping the fingers crossed until the next call for help is made—then digging up the streets, making repairs, refilling and repaving, resulting in disgruntled taxpayers—is very expensive as against an orderly economic sewer maintenance program. At least such has been our experience in Rockville Center.

For another splendid article on "Sewer Maintenance" see that by J. H. LeChard, Chief Engineer, Atlantic City Sewerage Co., in the Reference & Data Issue of 1939 (May) page 190, and that by E. P. Decher in the Issue of 1942 (June) page 172.

SEWER CLEANING WITH RUBBER BEACH BALLS

By A. M. RAWN, C.E.*
Los Angeles, Calif.

DURING construction of the sewer lines of the Los Angeles County Sanitation Districts, the problem of cleaning sand and debris from newly constructed lines gave rise to the trial of pneumatic rubber beach balls for this purpose. The use of beach balls was the outgrowth of the usual trial and error methods of using pull through devices, sluicing, use of fire hose and the like.

What is termed a beach ball in this narrative is the ordinary type of commercial pneumatic rubber ball commonly used at play grounds, at beach resorts and otherwise. The rubber is thin and the ball can be blown up to varying degrees of inflation at will. As furnished commercially, the balls have no covering and consist simply of elastic rubber. These balls are manufactured in sizes (diameters) of 6 to 30 inch diameter when fully inflated.

Procedure

For use in cleaning sewers the ball is first inflated and then wrapped in a covering of canvas or burlap, the edges of which are sewed together. A trail-line a little longer than the distance between manholes is then attached securely to the covering. The size of the ball and its covering should be such as to fit fairly snugly into the sewer leaving the downstream side of the manhole.

Immediately the ball is kicked into the pipe, sewage commences to back up in the manhole and continues to increase in depth until such time as its pressure is great enough to force water *under* the ball. (See sketch.) The ball then commences to move downstream through the pipe. Acting as a compressible floating plug it affords enough obstruction so that a continuous high velocity jet spurts under and to some extent around the balls, thereby sluicing all movable material ahead to the next manhole.

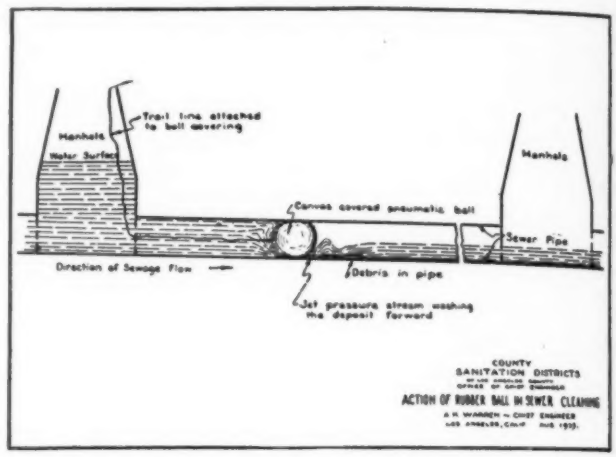
Should the ball encounter an obstruction which is immovable (for instance a joint fin or the like), it merely indents to the necessary degree and moves forward. About the only fixed obstruction which will stop the forward progress of the ball is a root mass or some similar obstruction tightly wedged into the pipe. Brick, stones, bottles, loose metal parts, broken pieces of pipe, sand, gravel and settled sludge are easily moved ahead.

If the ball stops momentarily, a pull on the trail-line is usually sufficient to set it again in motion and if the pipe is quite dirty the trail-line can be snubbed to a step in the upper manhole and the ball's progress retarded to the required degree as the lower manhole is approached, thus giving time for compelte removal of accumulated debris which the sewage has piled up ahead of the ball.

Much time may be saved by conserving the sewage pressure-head as the ball floats into the lower manhole. Just as the ball comes into view at the lower manhole, the snubbed trail-line is cast off and as the ball floats into the lower manhole with the gush of sewage, it is immediately kicked into the lower (outlet) pipe. The trail-line is picked up by fishing for it and the work proceeds as before.

In ordinarily dirty lines three men are employed as a crew and have cleaned in excess of four miles of sewer pipe in an eight hour working day.

The canvas covering serves two purposes: it permits ready attachment of the trail-line and also affords a measure of protection against puncture by razor blades, glass and sharp metal particles in the sewage sediment. The operation and maintenance crew carry along inner tube vulcanizing patches and small holes in balls are readily repaired on the job without much loss of time.



Sketch Showing Action of Beach Ball During Sewer Cleaning

A Real Test

As a measure of the utility of this method of cleaning, one outstanding example will be noted. A 24-inch diameter reinforced concrete pipe inverted siphon carries the sewage of one main under the Los Angeles River flood control channel. The siphon is about 800 feet in length. A ball, with trail-line attached, was inserted in the upstream end of the pipe; and, although, it took thirty-six hours to work its way through, there appeared ahead of it about a truck load of sand, gravel, bricks and boulders as well as a half-dozen flash boards which had dropped into the sewer at the upstream gate. The ball was put through again immediately and appeared at the outlets in less than an hour.

*Chief Engr., Los Angeles County Sanitation District, Los Angeles; Associate Editor W.W.&S.

NOZZLE REPLACEMENT ON TRICKLING FILTERS

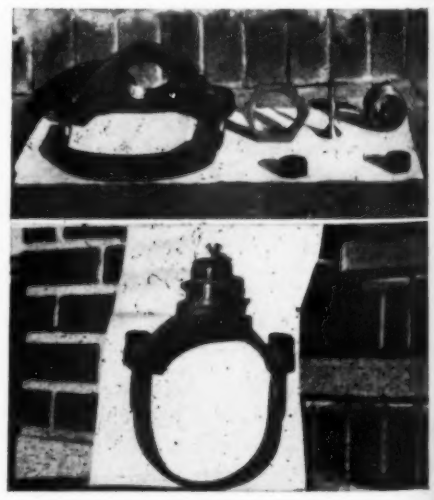
By ROY S. LANPHEAR
Worcester, Mass.

FLUSHING of the lateral distributors of the trickling filters at Worcester is done once each week by removing the end nozzle in each line (several at a time), and allowing the dosing tank siphons to operate once or twice. The threads in the pipe openings, into which the nozzles were screwed, were destroyed after a few months of this routine operation. Cast iron pipe, brass nozzles and a sewage containing strong acid and alkaline industrial waste liquors were also factors in such destruction.

Saddles, with washers and U-bolts, were first used. When the threads in a saddle gave out, a new saddle was installed. This operation proved successful and was used for some time. Additional purchases indicated that while the method was a success, the expense was quite an item in the cost of filter operation. Apparently galvanic corrosion was at the root of the thread wearing difficulty.

A later improvement was the use of a 2½x2-inch brass bushing in the saddle opening. This left the contact of the iron and brass threads undisturbed when removing the nozzles. No difficulty is now experienced and saddles with the bushings have been in use since May 1937. In lots of 200 the cost of the saddles, strap-type U-bolts, and bushings, was 84, 58½ and 47 cents each, respectively.

The accompanying cut shows the several component parts of the successful assembly.



SOME SEWERAGE OPERATING KINKS

By A. M. RAWN*

Associate Editor, Water Works and Sewerage

SEWER cleaning operations on a large trunk sewer system give rise to many notions and ideas regarding best methods. The writer presents a few operation and maintenance "kinks" which have been evolved entirely by the field operation forces on the Los Angeles County Sanitation Districts' system. Nothing new is claimed for the ideas and many an operation man may recognize in each, or all, a counterpart of what he daily practices.

Sewer Cleaning

The writer in the October, 1935, issue of WATER WORKS AND SEWERAGE described the use of rubber beach balls for cleaning lines up to 30 inches in diameter. Above 30 inches the balls are expensive and hard to obtain so that for cleaning circular sewers larger than 30 inches in diameter the district forces use a form of "hoe" shown as Fig. 1. It is simply and easily made and can be assembled in the ordinary manhole without much trouble.

In operation the "hoe" is assembled in the manhole and the proper sized flexible belting is attached to its downstream face. Belting is cut and fitted for each size of pipe from 30 inches to 60 inches for circular pipe, and is properly stiffened with sheet metal as is required in the larger sizes. With the exception of the belting attached to the face of the "hoe," the same equipment is used for cleaning all sizes from 30 to 60 inch pipe lines.

Following its assembly in the manhole, the "hoe" is thrust into the downstream pipe and the trail line is attached to the tail board holding the weights. The sewage backing up behind the "hoe" propels it through the pipe, moving any accumulated debris ahead to the manhole below.

The "hoe" is surprisingly efficient in cleaning the sides and invert of the line. Care must be taken to secure a reasonably close fit between the pipe and the outer edges of the belting so that the belting will have to flex forward to permit the escape of water collected behind the "hoe" face. If this precaution is taken, and the tail board is suitably weighted, one may be assured that just about anything movable below the backed-up water line will be shoved or sluiced ahead to the next manhole. Like the pneumatic cleaning ball, described in the October, 1935, issue of WATER WORKS AND SEWERAGE, the "hoe" moves easily over obstructions.

Root Cutting

Many types of root cutters have been manufactured and sold. A number have been tried on the districts' lines. None of them, however, has proven much more efficient than the simple, inexpensive device shown herein as Fig. 2. It is simply and easily made of ordinary butt-welded steel pipe of commercial sizes.

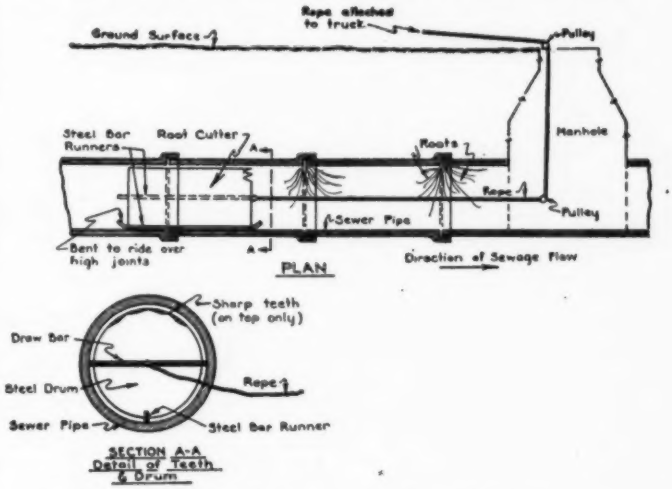


Fig. 2.—Root Cutter for Sewers of 12 to 36 In. Diameter.

*Chief Engineer, Los Angeles County Sanitation Districts, Los Angeles.

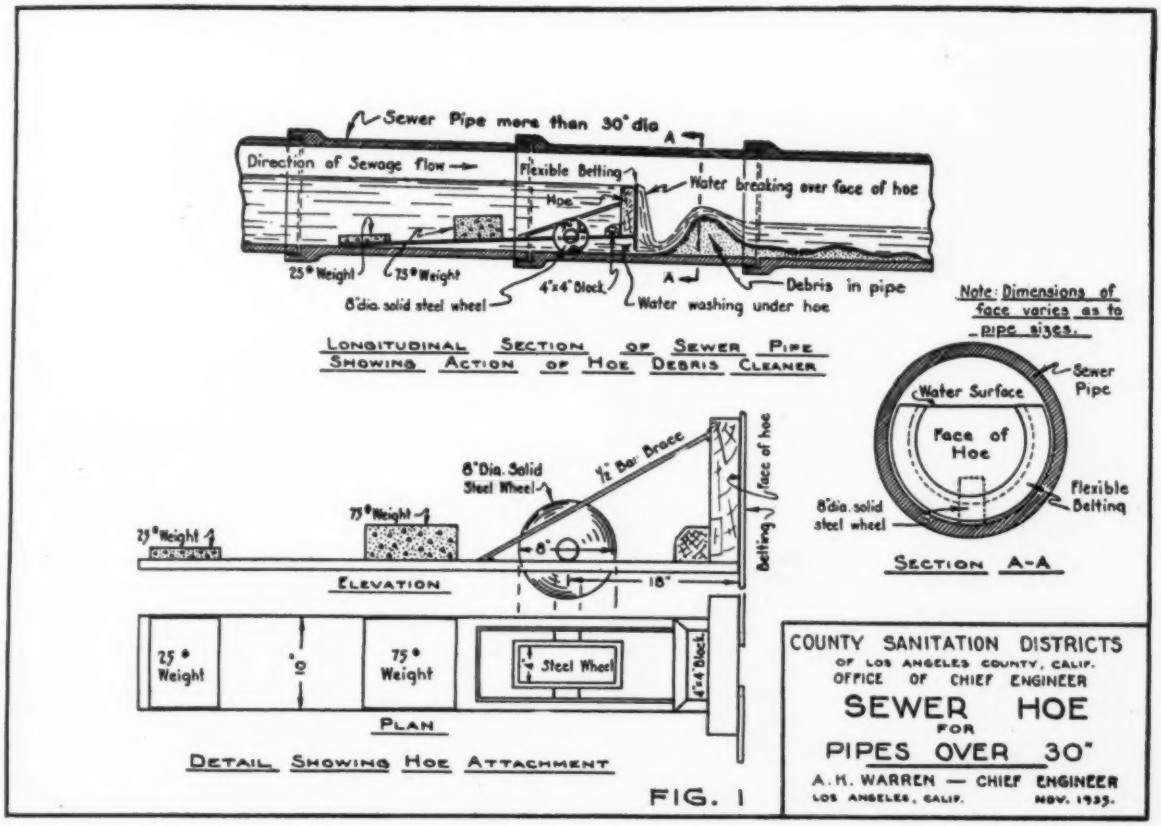


Fig. 1.—The Sewer "Hoe" for Cleaning Sewers Larger Than 30 In. Diameter.

To make it, take a piece of pipe about 18 inches long, serrate and sharpen the edges of both ends, and weld four shoes to the outside of the pipe. Affix halters for the pull and trail lines—and the job is done.

For an 8-inch line job use a 6-inch diameter pipe and ¼-inch strap runners or shoes. For a 12-inch line, use 10-inch pipe. A 12-inch diameter pipe is large enough for a 15-inch line, and so on. The sharpened notches in the pipe ends should be rather deep and wide so that they may pinch and hold the root, tearing or cutting it loose as its point of entrance into the line at which point it is usually quite small and relatively weak.

The pull line is thrust or pulled through with sewer rods, if it cannot be floated through the line. Pulley-blocks are then suitably arranged at the downstream manhole so that pulling may be done with the maintenance truck.

Lacking the proper diameter pipe for an operation, the operation and maintenance crew once manufactured a similar root cutter from a discarded water tank salvaged from a dump heap. It is still used upon occasion.

Air Relief Valve

Fig. 3 illustrates a type of air relief valve used in the 3½-mile (36 in. diam.) effluent pump line leading from the districts' sewage treatment plant. The valve pictured is installed at a summit in the line about 2,000 ft. from the plant where air must be tapped off if the line is to operate efficiently. It is also important that none of the effluent escapes through the blow-off.

A number of valves were tried but all operated with indifferent success until that sketched was installed. As may be seen, it consists of a simple float operating a steel ball valve attached to the end of a section of ½-inch pipe. The ball seats in a ground valve seat tapered to catch and center the ball as it rises. The valve case is constructed from a 5-inch diameter, butt-welded, steel pipe.

The secret of the mechanism is the small hole drilled in the ½-inch pipe near the ball. This is to permit admission of air into the light metal float, equalizing the pressures inside and out on the float and preventing collapse of the thin metal cylinder. When first constructed the hole was omitted and the float promptly collapsed, rendering the valve ineffective. When rebuilt, the air inlet hole was drilled and the valve, operating about three times a minute, has been in continuous service for more than six months.

It may be thought that condensation or spray might eventually fill the float cylinder with water, and the writer admits having shared such a belief at one time. Convinced, however, by the plant chief operator who designed and built the valve, that if the float did eventually fill it could be easily drained and put back into service, the installation was permitted. Now it has been proven that the principle is sound. No water escapes through the valve.

Grease Collection and Incineration

At the district's treatment plant, grease is skimmed manually from the tanks and burned. For a number of years skimmings were accumulated in galvanized iron cans and transported to drainage beds. When drained they were picked up in wheelbarrows and conveyed to the incinerator.

Handling the galvanized iron cans was a dirty and expensive item of labor as was the spreading on drainage beds and the reaccumulation and transportation to the incinerator. The grease draining beds were odorous in spite of all precautions and the incinerator ash was about 90 per cent sand—the latter being picked up with the grease from the beds.

The chief operator requested and received permission to construct the containers and transporting barrow.

The container or pan may be made any convenient size. That shown holds about 3 cubic feet. Placed in the bottom of the pan and standing on a rigid framework which elevates it an inch off the pan bottom, is a ¼-inch square mesh screen, the purpose of which is to provide drainage for the skimmings. The pan is so constructed that all drainage is toward the 1½-inch pipe shown in the right front of the pan at the base. Drainage from the skimmings goes directly back into the sewage tank.

The pan is filled with skimmings as they are taken from the sewage and permitted to drain for a couple of hours before being taken to the incinerator. Twelve such pans are in use

For transporting the pans to the incinerator the pneumatic tire wheel-barrow (illustrated) was constructed and is used. The operator wheels up to the high side of the pan, steps across it and engages the forward cross brace in the two forward pan dogs, then upon lifting the wheel-barrow handles, the rod welded across the back of the pan catches in the two swinging hooks

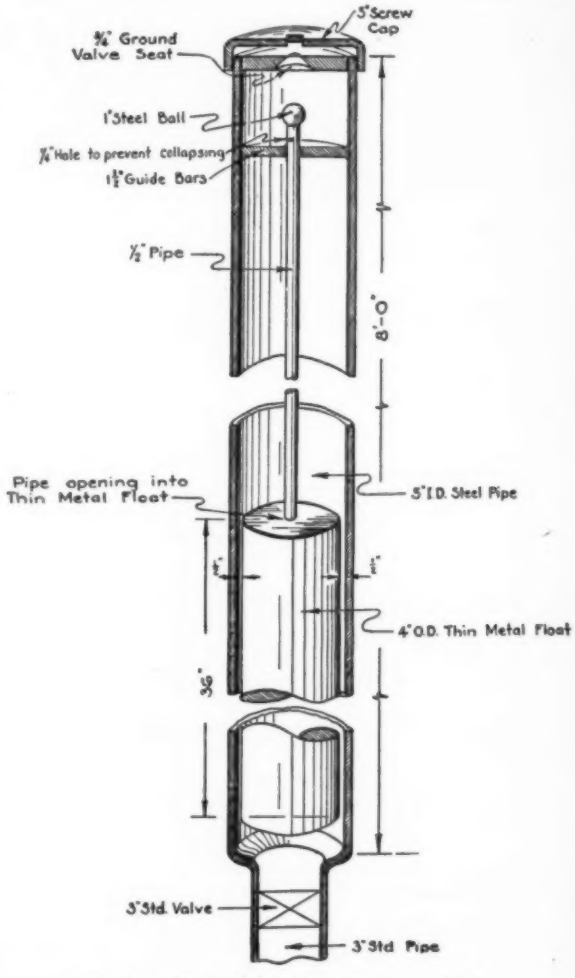


Fig. 3.—Air Relief Valve for Force Main.

attached to the barrow handles, and the load is securely engaged. The penumatic tire prevents wear on concrete walls and cross walks; makes for easy rolling.

It may be seen that when the pan is lifted the slope of the pan bottom is reversed and any water shaken out of the screenings during transportation stays in the pan until it is set down.

At the incinerator a movable sheet metal storage pan is located in front of the charging door. The operator swings the loaded wheel-barrow handles over the storage pan, engages the pan's back rod in the two forward dogs in the storage pan, releases his load and then tips the screenings into the storage pan with a hook.

The pans are cleaned daily with hot water and once a week with grease solvent. The pans and the wheelbarrow were all built in the plant shop by the plant operators.

Wheel Barrow Used for Transporting Skimmings Containers to Incinerator.

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Strong, Malleable Iron.

Triple Lock heavy duty sewer rod. Impossible to buckle or uncouple in the sewer. The tongue and groove eliminate wear on the hook, increasing the length of service.
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Free Trial—The Rods must Pay for themselves.

SECTIONAL STEEL RODS

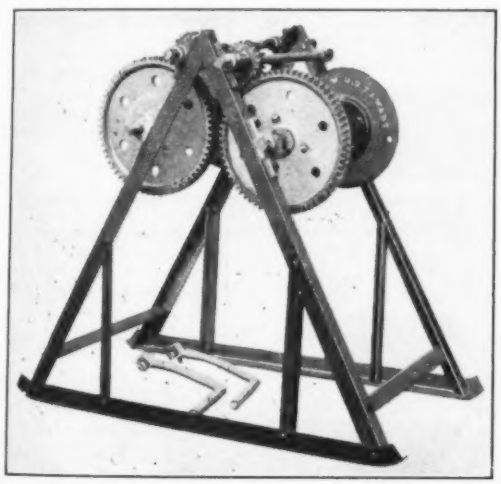
Double Lock highly tempered spring steel rods.

Rod length 3 ft., 5 ft. or 10 ft.

Rods connect by sliding in from the side. When the coupling is closed, a double lock prevents opening while in use.

May be operated from street level.

Two-Man Sewer Cleaning Machine



The Stewart single windlass "two-man" machine operates entirely over one manhole. The "two-man" windlass is a double drum machine; one drum holds the cable that pulls the bucket or tool into the sewer, the other drum holds the cable that pulls the bucket or tool out of the sewer.

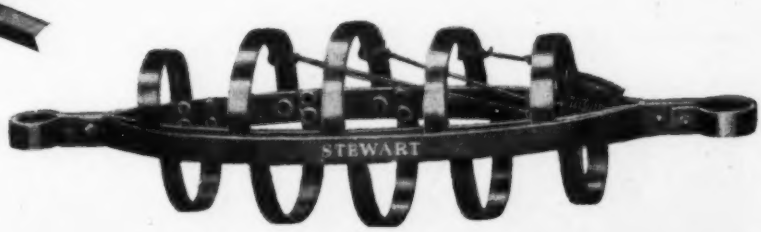
Rod Guide and Holding Frame

No. 22 Spear Screw—4" to 10"

No. 12—Open Screw— to

Guard Cage Collapsible Bucket—4" to 36"

No. 9 Stewart Root Cutter—4" to 15"



Patent Rights	
Date	Number
8-14-28	1,680,923
6-11-29	1,716,872
2-11-30	1,746,570
4- 7-31	1,799,269
11-10-31	1,831,153
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10- 7-29	Re.17,452
7-21-36	2,048,151

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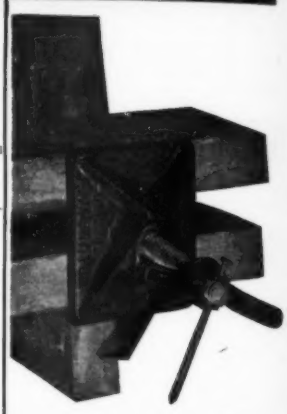
					Tensile Strength Ultimate	Maximum Allowable Working Load to Limit	
US-VL-1	⅜"	18"	(B-2) 3½"x5"	1,800 Lbs.	9,000 Lbs.	7,200 Lbs.	$1.25*
US-VL-2	⅜"	24"	(B-2) 3½"x5"	1,800 Lbs.	9,000 Lbs.	7,200 Lbs.	1.38
US-VL-3	⅜"	30"	(B-2) 3½"x5"	1,800 Lbs.	9,000 Lbs.	7,200 Lbs.	1.50
US-VL-4	⅜"	36"	(B-2) 3½"x5"	1,800 Lbs.	9,000 Lbs.	7,200 Lbs.	1.60
US-VL-5	½"	20"	(B-3) 4"x5"	3,200 Lbs.	16,000 Lbs.	12,800 Lbs.	1.55*
US-VL-6	½"	20"	(B-4) 5"x6"	3,200 Lbs.	16,000 Lbs.	12,800 Lbs.	1.65
US-VL-7	½"	24"	(B-3) 4"x5"	3,200 Lbs.	16,000 Lbs.	12,800 Lbs.	1.65
US-VL-8	½"	24"	(B-4) 5"x6"	3,200 Lbs.	16,000 Lbs.	12,800 Lbs.	1.75
US-VL-9	½"	30"	(B-4) 5"x6"	3,200 Lbs.	16,000 Lbs.	12,800 Lbs.	1.90
US-VL-10	½"	36"	(B-4) 5"x6"	3,200 Lbs.	16,000 Lbs.	12,800 Lbs.	2.05



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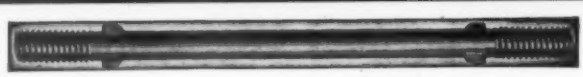

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LENGTH of Rod	Price per 100 Rods	App. Wall Width	LENGTH of Rod	Price per 100 Rods	App. Wall Width
12" or less	$3.00*	15" or less	12" or less	$4.00*	15" or less
13"	3.25	16"	13"	4.33	16"
14"	3.50	17"	14"	4.67	17"
15"	3.75	18"	15"	5.00	18"
16"	4.00	19"	16"	5.33	19"
17"	4.25	20"	17"	5.67	20"
18"	4.50	21"	18"	6.00	21"
19"	4.75	22"	19"	6.33	22"
20"	5.00	23"	20"	6.67	23"
21"	5.25	24"	21"	7.00	24"
22"	5.50	25"	22"	7.33	25"
23"	5.75	26"	23"	7.67	26"
24"	6.00	27"	24"	8.00	27"

*Rods under 12" in length knurled to prevent turning in concrete.

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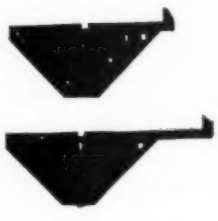

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PNEUMATIC GRIT WASHER AND EJECTOR

By NELSON M. FULLER
Superintendent, Water Works and Sewerage
Olean, N. Y.

THE removal of grit at the Olean Sewerage Treatment Plant is a very important detail of plant operation. Large quantities are received from storm drainage and from railroad repair shops. Also large amounts of sewage solids settle out in the grit chamber. Former methods of removal by hand, chain hoist and truck followed by burial were very disagreeable, being akin to cleaning out a large privy each week.

Formerly six man-days were required to carry out this operation, whereas the air lift system now in use washes the grit and disposes of it in thirty minutes. A mechanical conveyor system proposed for the removal of the grit would have cost $5,000. Using scrap materials and our own welders the air-lift pumping equipment herein described cost under $100.

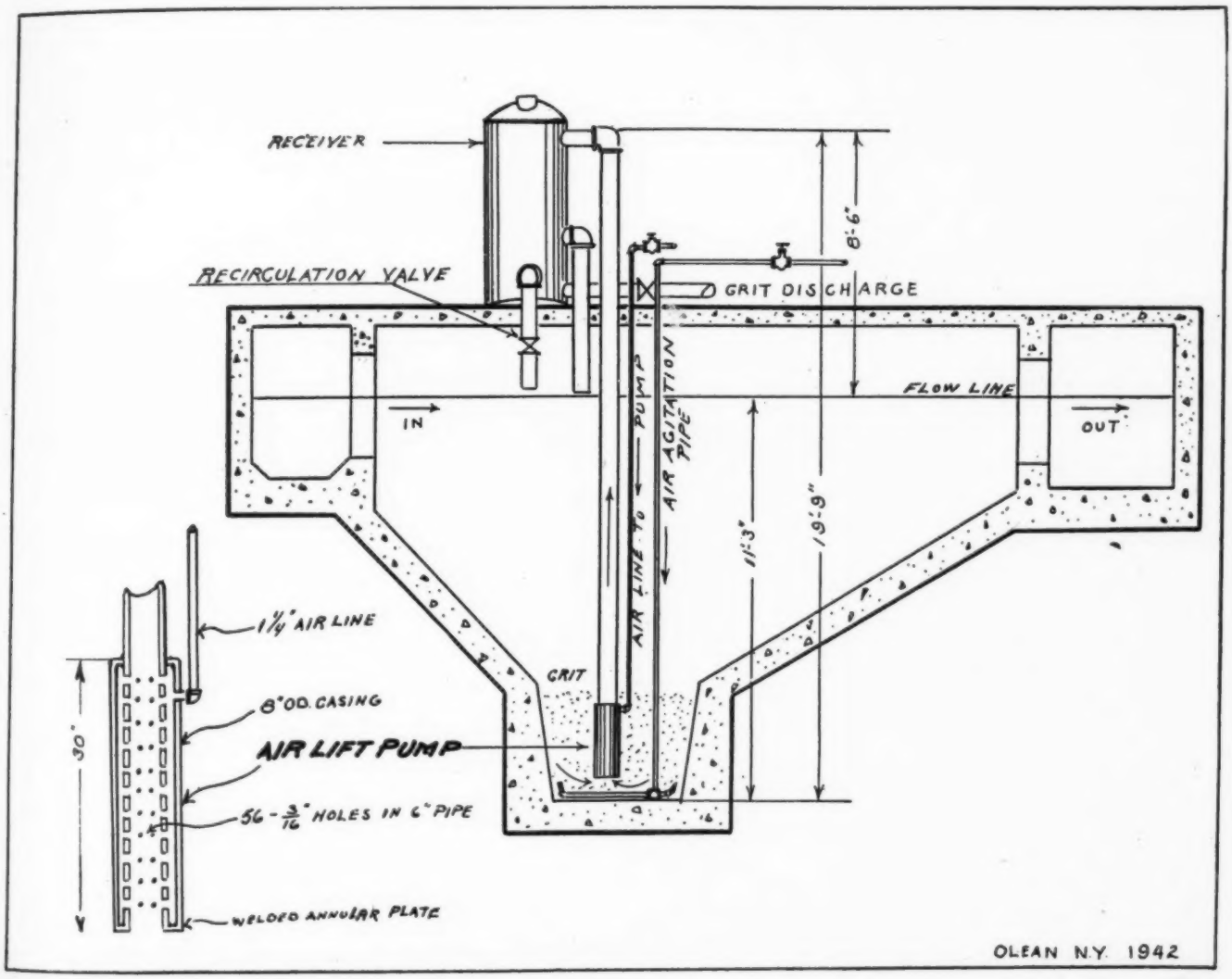
The air-lift system was limited in design to the use of air from our own portable air compressor of 105 cubic foot capacity. This permitted the use of a six inch flow pipe. An air lift pump is simple to construct after the correct size pipe is found which will give a uniform flow without "blowing through." The air water mixture must have a velocity upwards of ten feet per second. The foot-piece (the air and water mixing device) was designed so that in this case no obstruction to the free flow of grit, small sticks, and the rags which sometimes pass the bar screen could get fouled at the entrance.

The sketch accompanying this description shows a detail of the foot piece, which was made by boring fifty-six three-sixteenth holes in a thirty inch section of six inch pipe. This section of pipe was then placed into a piece of eight inch pipe and welded at both ends. The one and one-quarter inch air line was connected into the eight inch casing. A small tank was picked up as junk and was used for the air and water separator or receiver.

It will be observed from the sketch that the grit discharge line from the receiver can be closed and that the grit and solids can be recirculated to secure any desired period of washing action in the grit chamber proper. After a suitable period of washing the grit is allowed to settle and the sewage solids which are then in suspension in the grit chamber are flowed into the settling tanks. When this is completed the washed grit is removed by the air lift pump and discharged to the point of final disposal, which in our case is the Allegany River.

In order to clean out the corners of our grit chamber and to hold sewage solids in suspension air jets have been arranged to agitate the grit in these areas.

There is an excellent paper on this type of air lift adaptation in Sewage Tanks Journal, Volume V, No. 3, pages 509-522, by H. Blunk, Engineer, The Emscher Genossenschaft, Essen, Germany, titled "A Contribution to the Design of Grit Chambers," translated by G. P. Edwards of New York.



Details of the Olean Pneumatic Grit Washer and Ejector

DEFENSE MEASURES FOR SEWAGE WORKS

By SETH G. HESS
Chief Engineer
*Interstate Sanitation Commission**
New York City

DEFENSIVE measures as applied to sewerage system and treatment plants must protect such works against sabotage as well as damage from aerial bombardment. However, it seems unlikely that sewage works will receive the attention of foreign agents attempting sabotage because their efforts can be more effectively used elsewhere.

The plant operator and superintendent are sufficiently acquainted with their plant and system to know the points which are most vulnerable and where the greatest amount of damage could be done by the saboteur. By carefully listing these vulnerable points, the means of defense and protection become almost obvious.

The damage might result in the pollution of potable water supplies or in the flooding of important manufacturing plants, areas or services.

Although one should not go "witchhunting," those responsible should insure themselves that the employes in charge of vulnerable points are trustworthy. Registration cards for employes might include name, address, age, place of birth, citizenship, place of birth of parents, cities in which employe has lived the last five years. In small organizations, even this information is probably unnecessary.

Protection of Vulnerable Points

Having determined the vulnerable points, the means of protection against sabotage might include encasement, fencing, flood lighting and policing.

Protection against actual attack may include physical protection by encasement, bricking up openings of walls, etc., duplication, spare parts and organization for rapid repairs.

Again it is unlikely that sewage works would be the target of aerial attack; however, they may be mistaken for other types of plants, and, furthermore, from the air they appear to be attractive targets.

For physical protection, one might review some of the government manuals which have been issued, particularly the one, "Protective Construction—Structural Series Bulletin No. 1," prepared by the War Department, as well as the "Memorandum on Protective Construction" from the Office of Civilian Defense, and the "Protection of Industrial Plants and Public Buildings," also prepared by the Office of Civilian Defense.

Duplication of spare parts should be confined to those very special articles which cannot be readily replaced. One must be cautious not to build up a large reservoir of unnecessary reserve parts. A nice balance must be maintained between what is necessary and what is to be considered hoarding. One of the obvious needs is a secondary source of power as well as a secondary source of light in the sewage treatment works and pumping station.

Some Form of Mutual Aid Plan Desirable

The ability to rapidly repair any damage is probably the most important phase of the protection scheme. A careful inventory of all materials available and materials necessary is of primary importance. A complete inventory of equipment and tools as well as man power is a part of this scheme. Some arrangements should be made for the interchange of this information between nearby municipalities. In New York State, Maine, Massachusetts and other States the water works have already been organized along this line, and we understand that more recently the sewer departments are being organized along similar lines.

Contractors and their equipment become an important adjunct or auxiliary to the regular forces. In general, sewer departments are not as well prepared for emergency repairs as are the water departments. The sewer departments should, therefore, carefully organize an auxiliary whereby they would have at their disposal construction equipment such as excavators, pumps, bull-dozers, pavement breakers, and the like. The operators for all of this equipment must also be very carefully listed and made available. In this connection it is to be stressed that emergencies very frequently occur in the dead of night. Although it is not expected that a sewer will have to be repaired in the dark, certain emergency steps must very frequently be taken. It may be necessary to block off the flow or to prevent the discharge from a broken sewer from entering a potable water supply. One must be prepared for this type of emergency work. Furthermore, the necessary contractors' equipment and gangs should be so organized that they will be available the first thing in the morning following the damage.

Items to Consider

Ingenuity becomes a most valuable asset in the event of damage by aerial bombardment. Several items which may be anticipated in a sewage treatment plant include:

1. The control of damaged chlorine cylinders.
2. Means of applying disinfectant in the event that chlorinators are damaged.
3. Means of applying disinfectant at various points throughout the system.
4. Preparation to modify the type of treatment by reducing sedimentation time, etc.
5. Means of taking care of sludge in the event that digestors are damaged or put out of commission.
6. The use of settling tanks for sludge storage.
7. Makeshift sedimentation by using any available excavations or even bomb craters in the vicinity of the plant.

Notwithstanding the fact that many pumping stations are small targets, they are nevertheless vulnerable and a source of much trouble. The following should receive consideration:

1. Protect building and machinery against splinters.
2. Fire protection.
3. Means of by-passing pumps or damaged treatment plants.
4. Means of disinfecting during by-passing.
5. Auxiliary power.
6. Auxiliary pumps.
7. Portable pumps.

Emergency Equipment, Tools and Repair Materials

There is furnished herewith an inventory of the contents of the emergency truck of the Joint Meeting of Essex and Union Counties in New Jersey, as well as a list of the essential tools, equipment and materials for repair of sewers. They may serve as a check list to determine what additional tools, equipment or material may be necessary.

One must not fail to disperse the various materials and equipment throughout the municipality, being particularly careful to avoid placing too much material in the vicinity of either the treatment plant or the pumping station.

Since repairs must frequently be made where bomb craters occur, the pipe may have to be laid on fresh backfill. Extreme caution must be exercised in puddling the backfill and properly tamping it, as well as using such additional foundation facilities as may be required. It is well to consider the value of "Transite" or metal pipe for additional strength in carrying over bad foundations. Abroad repairs are in general permanent in nature. Seldom are temporary repairs made below street grade.

Those responsible are urged to review the system under their control and attempt to visualize what will be necessary should any one part of that system be made inoperative. Reasonable plans can then be made in advance to take care of such a situation.

Under the present conditions, eternal vigilance is not enough. It makes little difference why we lose the use of certain public utilities, whether it be through carelessness, sabotage or aerial bombardment. Their failure to operate, whatever may be the cause, is the enemies' objective. The fire on the Normandie, which resulted in that ship being out of service, was just as effective as though the enemy had bombed the ship. We must, therefore, guard against not only aerial bombardment, but sabotage and carelessness as well.

We must take preventive steps so that these things cannot happen and we must not have merely eternal vigilance but we must apply aggressive vigilance.

*Representing the States of New York, New Jersey and Connecticut.

Contents of Emergency Truck

Joint Meeting of Essex & Union Counties of N. J.

1 Line Level
5 Pairs Safety Glass Goggles (for chipping concrete, etc.)
3 Carpenters' Saws 1—24", 2—28" rip and cross-cut
1 Pistol-grip Hack Saw
1 Keyhole Saw—16"
1 10 oz. Brass Plumb Bob
1 Stanley Combination Square—18"
1 Spirit Level—24"
1 Spirit Level—28"
1 Carborundum Sharpening Stone—1"x2"x7"
1 Steel Framing Square—16"x24"
1 Steel Square—8"x12"
1 Carpenter's Steel Square with wooden handle—4"x9"
3 5-cell Eveready Focusing Flash Lights
2 2-cell Eveready Water-proof Rubber Flash Lights
12 Extra Batteries for Flash Lights
6 Extra Flash Light Bulbs for 2 & 5-cell lights
1 Portable Electric Lantern—#6 Harris Bros.
2 Extra #6 Batteries for the above lamp
3 Mirrors—18½"x13½"
1 Stanley Block Plane—2"x6"
1 Stanley Wood Plane—2"x14"
1 Bit-Brace
1 Portable Red Diamond Hand Grinding Wheel
1 Davis Inhalator, with Oxygen Tents
1 Wolfe Oxygen Deficiency Lamp
1 Single Pulley (metal)—5"x12"
15 ft. 2" Link Chain
6 ft. 2" Link Chain
1 #10 Gauge Malleable Iron Wire—35 ft. roll
1 #16 Gauge Malleable Iron Wire—50 ft. roll
1 Davis All Service Gas Mask with Blower for 2 men
1 Davis First-Aid Kit
3 Dupor Rubber Respirators Canisters
24 Filter Pads for the above
12 Face Cloths for the above
1 Mine-Safety Hydrogen-Sulfide Detector
1 Davis Combustible Gas Indicator
200 ft. Wooden Sewer Rods—3 ft.
500 ft. Flexible Sewer Cleaning Rod and necessary attachments
1 Quart Pyrene Fire-Extinguisher
1 Steel Measuring Tape—100 ft.
1 Steel Measuring Tape—50 ft.
1 Ax with 18" Handle—6"
1 Ax with 18" Handle—7"
2 Half-Pint Oil Cans
1 Wrecking Bar—30"
2 Wrecking Bars—24"
1 Wrecking Bar—18"
3 Manhole Hooks—¾x20"
3 Hydrant Wrenches—¾x18"
1 Assorted Rubber Hose Washers—1 box
1 Assorted Wood Screws—1 box
2 Spanner Wrenches—12"
2 Spanner Wrenches—11"
4 Hydrant Adapters—2½"
1 Hydrant Adapter—2"
1 2½" Brass 15" long Shut-Off Hose Nozzle
2 Traffic Safety Stands—4"x26"
8 Traffic Flags—20" long
8 Traffic Signs—15"x15"
8 Wire Brushes—1"x12"
2 Wire Brushes—2½"x8"
1 Telephone Gas Mask Set Complete
3 Brick Laying Trowels—9"
1 Set Sidewalk Masonry Tools
1 Brick Hammer—8"
2 Cork Floats—12"
1 Steel Float—12"
1 Bale Hook—12"
1 Sewer Spear—42"
5 Galvanized Pails—14 qt.
1 4 Prong Sewer Hook—52" long
1 3 Prong Sewer Hook—48" long
1 Steel Garden Rake—5½"x15"
1 Mason Hoe—5½"x9"
1 Standard Size Breast Drill—14"
1 Set of Wood Chisels—¼"-½"-¾"-1"-1¼"-1½"
1 10" Goodell-Pratt Automatic Drill
1 Van Dorn—110 Volt Heavy Duty ½" Electric Drill
24 Keyhole Saw Blades
1 14" Half Round File
2 12" Half Round Files
1 7" Half Round File
3 12" Flat Files
1 9" Flat File
1 7" Flat File
1 5" Flat File
7 Wood handled Screw Drivers—5"-6"-8"-9"-11"-14"-16"
1 Cutting Pliers—7"
1 Cutting Pliers—6"
1 Gas Pliers—6"
1 Tin Snips—7"
1 Tin Snips—12"
1 Auger-Bit—(1"x16")
1 Set of 13 Wood Drills—¼" to 1"
10 Star Drills, Sizes—1"x18" — 1"x12" — ⅞"x11" — ⅞"x8" — ⅝"x11" — ½"x18" — ½"x12" — ½"x9" ½"x8"
2 Carpenter Hammers—12"
3 Machinist Hammers—12"
32 Steel Chisels, various sizes—⅞x8 — ¾x12 — ¾x7 — ½x6 — ⅜x5 — ⅝x6 — 1x12 — 1x7 — 1¼x16 — 1¼x10 ¾x18
25 Bullpoint, sizes—1¼x20 — 1¼x14 — 1¼x12 — 1¼x10 — 1⅛x15 — 1⅛12 — 1⅛x11 — 1⅛x9 —1x18 — 1x12 — 1x9 — 1x28 — ¾x11 — ⅝x18 — ⅝x10
1 Sledge Hammer—12 lb.
1 Sledge Hammer—10 lb.
2 Sledge Hammers—5 lb.
4 Sledge Hammers—4 lb.
2 Grub Ax and Handles—16"
4 Pick Axes with Handles—20"
1 Bolt Cutter—3 ft.
1 Hoe & Handle 4" x 6 ft.
1 8" Ax with 3 ft. Handle
2 Brush Hooks with 3 ft. Handles
3 Folding Rulers—6 ft.
1 Stillson Wrench—2 ft.
1 Stillson Wrench—18"
1 Stillson Wrench—14"
1 Funnel—6"
1 Funnel—10"
1 Walker Hydraulic Jack—3 ton
1 Nail Box (9"x25") with assorted nails
1 Mitre Box—18"
1 Set, Williams Socket Wrenches
1 Steel Tamper—6"x5 ft.
2 10" Square Shovels with 3 ft. handles
3 9" Round Nose Shovels—3 ft. handles
1 10" Round Nose Shovel—5 ft. handle
1 10" Square Shovel—5 ft. handle
2 Corn Brooms—4 ft. handles
3 Steel Crow Bars—1"x5 ft.
1 Push Broom—18"—5 ft. handle
2 50 ft. lengths ¾" Emerald Cord Hose
2 25 ft. lengths ¾" Rope for Lifting
1 ½" Block & Tackle with 100 ft. first grade Manila rope
100 ft. 1" Manila Rope
100 ft. ¾" Manila Rope
1 Canvas Safety Belt with 35 ft. of Manila Rope
1 50 ft. #14 Wire Extension Cord with plugs
1 75 ft. #14 Wire Extension Cord with plugs—for a Portable Elec. Generator
2 50 ft. lengths 2½" Double Jacket Cotton Fire Hose
2 50 ft. lengths 1" Hose for Gas Mask
2 Pr. Rubber Wading Boots
5 Pr. U. S. Royal Storm King Boots
5 ¾ lengths Med. Wt. Rubber Coats
5 Fibre Safety Helmets
2 Pr. 30" Rubber Gloves

Tools, Equipment and Material For Repair of Sewers

(Developed with the Assistance of Mr. Jacob L. Lenox)

Equipment

Compressor, air with jack-hammer, paving breaker, bull points, hose, etc.
Electric generator, portable
Pumps, 3" diaphragms, power
Pumps, 3" centrifugal, power
Respirator
Tar kettle, 200-lb. capacity
Truck, 1½ ton dual tire
Flood lights

Material

Barricades
Brick, common and vitrified
Burlap bags
Cement
Calcium chloride
Drum, 50 gal
Gasoline
Horses, wooden, various sizes
Jointing compound
Kerosene
Lead
Lead wool
Lubricating oil
Lumber, 2x4, 2x10, 4x4, 6x6, #1 com. fir
Manhole blocks
  Heads
  Steps
Nails, assorted
Oakum
Pipe stock depending on system
Plaster of paris
Roofing paper
Sand
Wire, #10 and #16, annealed

Tools

Adze
Axe
Bars, Crow, 5'
Bars, pinch (wrecking), 30"
Block, wood, double
Bolt cutter, #4
Boots, Hip and ¾, assorted sizes
Broom, street
Bull points, ⅞x18"
Chain, assorted sizes and lengths
Chisels, assorted cold
Climbers, lineman's
Digger, post hole
Dipper
Files, assorted
Fire extinguisher
Flag, danger
Furnace, plumbers' gas
Gloves, rubber
Goggles, safety
Hacksaw frame and blades
Hatchet
Hoist, 1 ton chain
Hose, ¾" garden
Hook, brush and handle
Hook, cant
Hammers, ball peen
Hammers, carpenter
Hammers, caulking
Hammers, sledge
Iron, caulking
Joint runner, asbestos
Jack, screw, trench, ass't length
Jack, house
Ladder, extension to 20'
Lanterns, red and white globes
Level, carpenter 24"
Line, mason
Mattocks
Moccasin, wool boot
Pails, 12 qt. heavy galv.
Picks
Pliers, cutting
Plumbing bob
Plugs, rubber expansion, 4, 6, 8, 10, 12"
Pump, canal 10'
Rope, ¼, ½, ¾
Ruler, folding 6'
Saws, hand 26", #8
Saws, 2 man cross cut, 5'
Screw driver, 12"
Shovels, Short, round point
Shovels, Short, square point
Shovels, Long, round point
Stretcher
Tarpaulin, 20x20', 10 oz.
Tool box, portable on wheels
Torches, bomb type
Tripod, 2" pipe
Trowel, 9"
Vise and pipe stand
Wedges, oak, 3"x3"x14"
Wheel barrows
Wrenches
  Adjustable 6", 8", 10"
  Stillson 18", 24", 36"
  Hydrant
  Valve

THE AMERICAN BRASS COMPANY

General Offices: WATERBURY, CONNECTICUT

ANACONDA
from mine to consumer
REG. U.S. PAT. OFF.

Everdur Metal

For Sewage Treatment Equipment, Reservoir and Water Works Service

FOR SEWAGE TREATMENT EQUIPMENT

Niagara Falls, New York, Sewage Disposal Plant, showing three of six Everdur Disc Screens. This plant handles the effluent from most of the manufacturing plants in the city; consequently, the sewage is highly corrosive in character—at times carrying as high as 800 p.p.m. of chlorine.

Close-up of one of the Everdur Screen Plates shown above. The plate is partially covered with coke which is used for screening. Part of the coke has been removed by the rotary brushes shown in the picture. The organic matter from the sewage is incinerated and the coke reclaimed for future use.

Everdur* Metal, The American Brass Company's copper-silicon alloy, is offered as one of the most versatile materials available for the fabrication of sewage treatment equipment. It has given superior service in this field for more than sixteen years.

Everdur, made in several types, consists essentially of copper and silicon, with controlled additions of other elements. The tensile strength, in wrought form, ranges from a minimum of 50,000 lbs. per sq. in. for annealed tank plates to approximately 100,000 lbs. per sq. in. in cold worked forms. Among its other desirable properties are ready workability, either hot or cold, and high resistance to fatigue. Everdur is as fully resistant to corrosion as pure copper and, in some instances, more so. It can be readily welded, brazed or soldered by most of the common methods.

Application

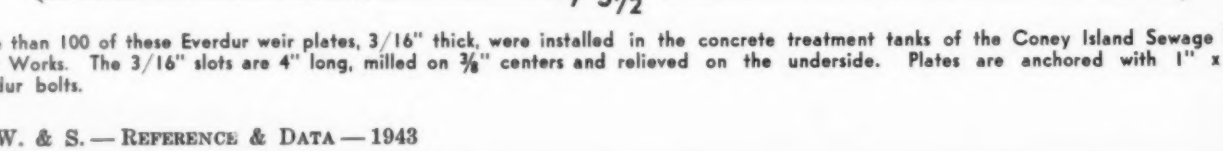
The principal applications of Everdur for sewage treatment are as follows: coarse and fine screens, swing gates, built-up sluice gates, coarse bar rack aprons, effluent weirs and scum weirs, scum baffles and brackets, troughs, screen hoppers, orifices, baskets, anchors, ladders, float gage chain, valve springs, manhole steps, walkways, bars and plates, bolts and nuts, Electrical Metallic Tubing and Rigid Conduit.

Advantages

Because of its high strength, corrosion-resistance and weldability, Everdur has effected considerable economies in equipment previously made of heavy iron castings. Relatively lightweight wrought sheets of Everdur, assembled by welding, provide much lighter, more easily operated, and more durable equipment.

Everdur Metal costs less than most high strength corrosion-resistant alloys, and not only meets many of the definitely determined corrosion problems of sewage treatment, but also provides the necessary additional protection where the forces of corrosion are variable.

*Everdur is a trade-mark of he American Brass Company. Registered in the U. S. Patent Office.



More than 100 of these Everdur weir plates, 3/16" thick, were installed in the concrete treatment tanks of the Coney Island Sewage Treatment Works. The 3/16" slots are 4" long, milled on ⅜" centers and relieved on the underside. Plates are anchored with 1" x 2½" Everdur bolts.

THE AMERICAN BRASS COMPANY

FOR RESERVOIR AND WATER DISTRIBUTION SYSTEMS

Everdur Metal is performing highly satisfactory service as an engineering material in reservoir and water distribution systems. Convincing evidence of the superiority of Everdur for water handling equipment lies in the fact that it had been adopted before the war by the majority of manufacturers of automatic domestic water heaters as the standard tank material for rust-proof tanks.

Application

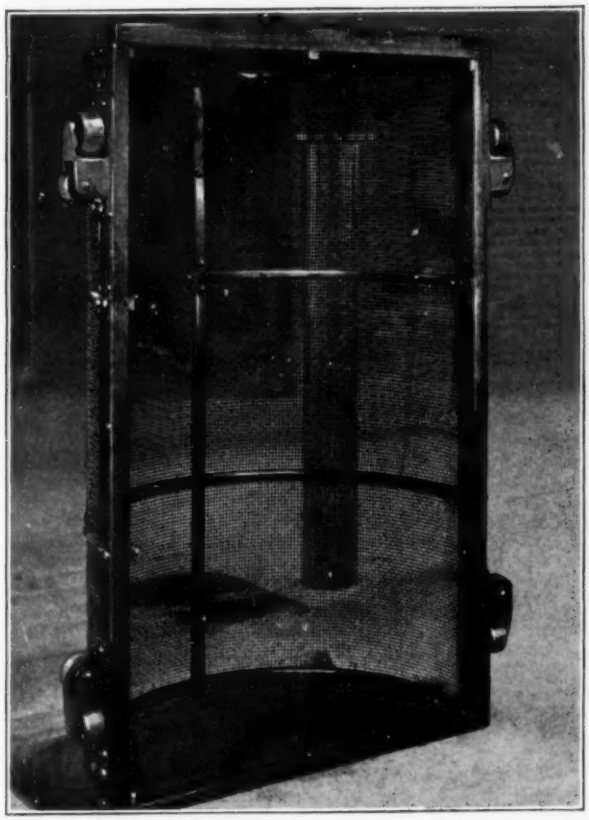
Its chief uses may be listed as: screens, screen frames, spillway fittings, flash board supports, bolts, steps, valve s'ems, flush box fittings and pipe. The largest use of Everdur for underwater equipment has been for concrete revetment installations in Mississippi River flood control projects. Hundreds of thousands of pounds of Everdur in the form of solid wire, stranded wire, clips, saddles, U-bolts and nuts have been used in the making, assembling and laying of the articulated concrete mattresses, which provide the river bank protection.

Advantages

Durable, non-corroding installations in masonry
Fabricating economies because of its weldability
High tensile strength
Weldability by most of the commonly used welding methods

Engineering Service

Members of the Technical Department of The American Brass Company will be glad to confer with Consulting and Sanitary Engineers regarding specific sewage treatment or reservoir and water works systems. A request for this engineering service entails no obligation.



Everdur copper-silicon alloy screen frame in the gatehouse of the New Haven Water Company, New Haven, Conn.

Publications Furnished on Request

E-11 (Everdur for Sewage Treatment Equipment)
E-5 (Applications, Physical Properties and Constants)
E-6 (Everdur Bolts, Screws and Accessories)
E-1 (Everdur Casting Ingots)
E-13 (Everdur Tanks and Equipment)
E-22 (Anaconda Electrical Conduit)

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IN CANADA:

Anaconda American Brass Limited, *General Offices,* New Toronto, Ontario
Montreal Office: 939 Dominion Square Building

LINK-BELT COMPANY

Specialists in the Manufacture of Equip- *-ment for Water and Sewage Treatment Plants*

PHILADELPHIA 2045 W. Hunting Park Ave. | CHICAGO 300 W. Pershing Road | LOS ANGELES 361 S. Anderson St. | CLEVELAND 548 Rockefeller Bldg.

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In Canada—Link-Belt Limited—Toronto; Montreal; Vancouver; Swastika
Shovel-Crane-Dragline Division—Link-Belt Speeder Corp., Chicago; Cedar Rapids

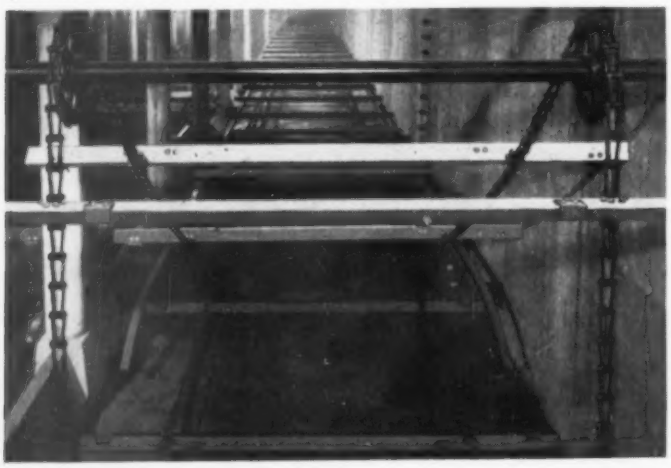
Consulting, municipal and sanitary engineers, and plant operators everywhere are invited to get the latest information on the Link-Belt products for sewage treatment, sludge collection, screening, grit washing, mixing and other services. Link-Belt installations are in service at hundreds of sewage and water treatment plants throughout the country . . . cities . . . towns . . . communities . . . army camps . . . air fields . . . naval bases . . . ordnance works, etc. Catalogs sent on request.

STRAIGHTLINE COLLECTORS

Link-Belt STRAIGHTLINE Sludge Collectors for the removal of sludge from rectangular settling tanks consist of two strands of especially processed malleable chain from which are suspended at uniform intervals scraper flights usually made from red wood. Features are peak-cap bearings, pivoted flights, cross collectors for larger tanks, and positive sludge removal at a slow, uniform speed. Automatic or semi-automatic skimming equipment is furnished when required.

Many installations are now in service in all parts of the country and range in size from the smaller type plants as at Tappahannock, Va., with a capacity of 80,000 G.P.D., to larger installations such as Ward's Island, N. Y., with a capacity of 180,000,000 G.P.D., and Southwest Plant, Sanitary District of Chicago with a maximum capacity of 600,000,000 G.P.D.

Many features of the Link-Belt STRAIGHTLINE Collector are patented. Send for Book No. 1742.



Shows use of scum collecting screw conveyor on Link-Belt Circuline collector in 100-ft. diameter primary settling tank.

Link-Belt Circuline sludge collector is 70-ft. diameter final settling tank at an army camp sewage treatment plant, equipped with two rubber-tired wheels, well guarded, which run directly on concrete wall of tank.

CIRCULINE COLLECTORS

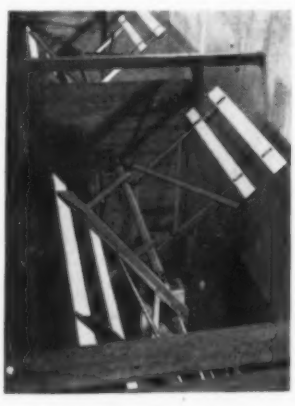
Link-Belt CIRCULINE Collectors for the removal of sludge from round tanks consist of a flight conveyor suspended from a bridge, one end of which is pivoted at the center and the other end is mounted on standard rubber-tired wheels which travels around at circumference of the tank. Features are: positive, slow, uniform speed; positive sludge removal and excellent distribution of flow throughout the tank; improved, automatic scum collecting screw conveyor and scum receiving hopper as standard equipment.

Send for Book No. 1642.

STRAIGHTLINE MIXERS FOR FLOCCULATION TANKS

Link-Belt STRAIGHTLINE Mixers of the vertical or horizontal type have proved their value in reducing chemical costs and promoting efficient flocculation in water and sewage treatment plants. They consist of a shaft to which is fastened arms which carry either wood or steel paddles that can be pivoted so that the flights can be adjusted to obtain the exact degree of uniform agitation. The maximum circumferential speed of the mixers for flocculation tanks is 1.8 f.p.s., and the minimum speed is about half of that. A gradual decrease in speed of the units is desirable for efficient flocculation.

Send for Book No. 2042.



BIO-FILTRATION SYSTEM FOR TREATING SEWAGE

STRAIGHTLINE Collectors in primary and secondary settling tanks at Bio-Filtration Plant, Camarillo, Calif.

Bio-Filtration Sewage Treatment System with Link-Belt STRAIGHTLINE and CIRCULINE Collectors brings new advantages. The system consists of high rate shallow filter beds and recirculation of the effluent from the filter beds to the primary tanks. Features are great flexibility, high rate of B.O.D. loading and the ability of such a plant to handle strong domestic and industrial sewage in single-stage or two-stage treatment, as required. A large number of installations of this type are now in operation or in course of construction. Send for Folder No. 1881.

STRAIGHTLINE BAR SCREENS

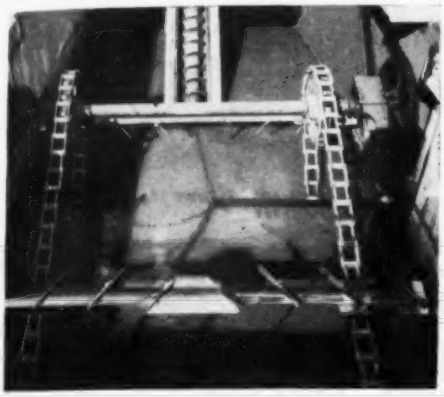
Link-Belt STRAIGHTLINE Mechanically Cleaned Bar Screens have spaced parallel bars on which the larger floating solids in incoming sewage collect, and a mechanically operated rake for removal of the accumulating solids, thus assuring an even flow of sewage through the channel. The machine may be set vertically or inclined, and used in small or large plants.

STRAIGHTLINE Mechanically-Cleaned Bar Screen at Sewage Pumping Station, Lackawanna, N. Y. Nussbaumer & Clark, Inc., Consulting Engineers

Send for Booklet No. 1587.

STRAIGHTLINE GRIT COLLECTORS AND WASHERS

The Link-Belt STRAIGHTLINE Grit Collector and Washer collects the settled grit and frees it from putrescible organic matter. This unit consists of a scraper type collector with pitched flights, and an inclined washing and dewatering screw to which the collector conveys and into which it discharges the grit at bottom of tank. Send for Book No. 1942.



INDUSTRIAL WASTE SCREENS

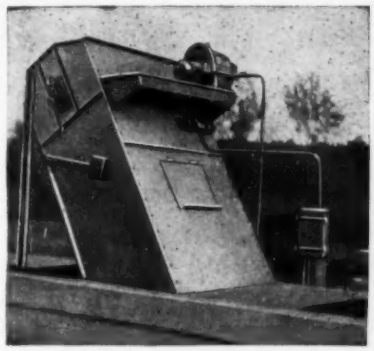
The Link-Belt Industrial Waste Screen is an efficient and economical unit for the removal of objectionable suspended solids from industrial waste before the water is discharged into sewers or streams. The screenings come off the machine with a minimum of moisture. Units are available in several sizes and with coarse or fine screen medium. Wastes from canneries, textile mills, steel mills, etc., are handled successfully by these screens. Send for Book No. 1877. We also manufacture rotary screens for similar service.

This "Liquid" waste screen separates refuse from water as received from beet pulp washers before discharging to sewage system.

TRITOR SCREENS

The Link-Belt Tritor Screen is a combination of screen and grit chamber. It is especially designed for medium and small size plants. Its main elements are a hopper, a bar screen, and a bucket elevator for removing grit from hopper, the buckets being perforated for drainage. On return run, rake teeth on buckets clean the screen. Adjustable baffles regulate velocity of flow through the hopper.

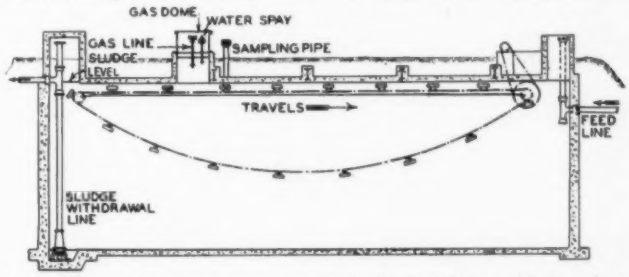
Booklet No. 1587.



TRITOR Screen, fully-enclosed type, at Salisbury, N. C. Sewage Plant.

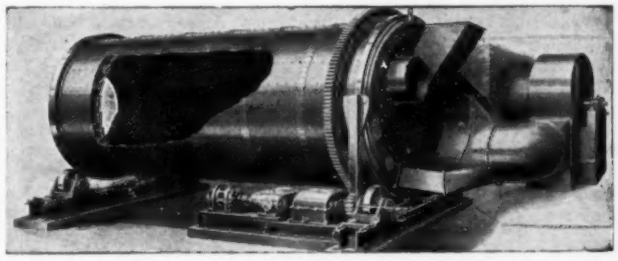
STRAIGHTLINE SCUM BREAKERS

The scum breaker is used in digestion tanks to paddle down and submerge the floating scum. It consists of two strands of chain from which are suspended pitched flights which agitate the scum and carry it below the surface of the supernatant liquor. Features are rugged construction and automatic take-up where required.



ROTO-LOUVRE HEAT DRYERS

The Link-Belt Roto-Louvre heat dryer consists of a mechanically rotated horizontal drum with a series of internal channels near the circumference into which hot air enters, leaving then through slots to enter the inside of the drum, which contains the sludge; hot air entering the channels only when they are near the bottom, and thus all passing through the sludge. Due to this intimate contact of drying medium with material, high efficiency is obtained keeping floor space requirements at a minimum. Dry material discharges from dryer at a low temperature of about 150°F and the unit is equipped with automatic controls that maintain the desired discharge moisture content. No cascading takes place, thereby minimizing degradation and wear. Send for Book No. 1911.



ENGINEERING DATA BOOKS ON ANY OR ALL LINK-BELT PRODUCTS WILL BE SENT ON REQUEST

OTHER LINK-BELT WATER PURIFICATION and SEWAGE TREATMENT PLANT EQUIPMENT INCLUDES: Traveling Water-Intake Screens; P.I.V. Gear Variable Speed Drive for Pumps; Coal and Ashes Handling Machinery; Car Spotters and Haulage Systems; Shovels-Cranes-Draglines — Crawler and Rubber-Mounted types; and a complete line of elevating, conveying and power transmitting equipment. Catalogs sent on request.

9160

TRITURATION OF SEWAGE SCREENINGS

Operating Experiences at Oneonta's Sewage Treatment Plant

By WILLIAM W. WATKINS

Engineer and Superintendent, Sewage Works Disposal

Oneonta, New York

In November, 1933, Oneonta, a city of about 13,000 people, in Southern New York State, put its new sewage treatment plant into operation. The plant consisted of a mechanically operated bar screen, settling tanks with mechanical sludge removal, separate sludge digestion tanks and glass covered sludge drying beds.

Mechanical Screening

When the plant was constructed, the screen chamber was equipped with a "Rex" Mechanical Bar Screen, supplied by Chain Belt Co. of Milwaukee. This screen was operated automatically by time clocks, set to start and stop the screen mechanism at such intervals as experience had shown to be necessary.

Varying conditions in the sewage flow caused too much head loss through the screen and corresponding changes in velocity in the settling basins, so, in 1935, the screen was equipped with a direct operated single float which resulted in a more uniform flow through the screen and the settling basins.

At Oneonta, as at most sewage plants, the real problem has not been that of *removing* the screenings from the sewage, but that of hygienic *disposal* of the screenings removed.

Screenings Disposal

For four and one-half years—when weather conditions permitted—we dug ditches and carted the screenings out for burial in what the men call the "graveyard"—a piece of city-owned property adjacent to the plant and about 200 yards away from the screen. If too much ditch was dug in the fall it caved in before it was used up. After the ground froze it was economically impossible to dig more ditches until spring. Consequently in the spring it was necessary to spend a week or more with a crew of men and trucks getting rid of the screenings that had been dumped but couldn't be buried.

The daily average of screenings removed has varied widely from a maximum of 33.4 cubic feet to a minimum of 4.43 cubic feet. And on one occasion (not storm flow), the total screenings for one day was 66 cubic feet.

With such erratic quantities of screenings it was necessary to keep a large amount of open ditch available at all times, as the operator did not have time to dig his own ditches as required. In addition to the extra cost of ditching it was necessary to have a small truck convenient at all times in order that the full cans of screenings might be emptied and not allowed to accumulate for too long periods.

Burying the screenings took about 2 hours of the operator's time, besides the extra help for ditching and the cost of the truck, making the total cost of handling the screenings about $2.00 per day. Since there is no definite relation between sewage flow and screenings handled, costs per million gallons have little meaning, and therefore have not been recorded.

Early in 1937 it was decided that the cost of handling screenings was too high and that something must be done. In coming to this decision, the element of nuisance admittedly had a bearing. After a survey of the field for satisfactory equipment for shredding or macerating screenings for treatment with the sewage, a "Rex Triturator," manufactured by the Chain Belt Company of Milwaukee, was purchased, and installed in June, 1937, for shredding all screenings removed by the automatic bar screen.

The "Triturator" has been operated every day since its installation. It has saved time for the operator, money for the city, and has gotten results in digestion that we had not expected, but which are very gratifying. The digester gas yields have revealed greater uniformity and higher values, consistently.

Benefits from Trituration

From an operating standpoint, the time required by the operator for putting the day's screenings through the Triturator is about one-half hour to one hour—instead of the two hours or more formerly required to bury the screenings. The operator has the saved time to devote to less objectionable and more valuable duties.

From a sanitary or cleanly standpoint, there is no comparison between the old and the new methods. There are now no cans to fill up, to slop over in trucks, to be washed up when empty, or left to draw flies.

From a strictly monetary standpoint, trituration of screenings shows a money saving benefit which can be actually measured. Some of these follow.

The cost of ditching is eliminated. The use of a truck is no longer necessary. These combined items have figured $1.73 per day at Oneonta. Against this is the cost of power and water consumed by the Triturator. Maintenance is not figured in either case, because such has been negligible. The operator has at least an hour more time available each day, and has been able to do some of the work for which we formerly had to hire extra help from time to time.

At an estimated consumption of 25 gallons of water per minute and forty minutes' operation per day, the cost of water at current retail rates is 13 cents per day. A five horse power motor, running at full load, will consume about 4.5 K.W.H. per hour. This figures twenty-eight cents per day at current rates paid. This makes a total additional cost of forty-one cents per day, not counting in depreciation and interest charges.

Gross Savings by Trituration	$1.73
Less power and water cost	.41
Net savings by Trituration (per day)	$1.32

Operating Cost and Savings

From the time that the plant was put in operation until the Triturator was installed, the average daily quantity of screenings has been 12.88 cubic feet. While there is no way of measuring the screenings, it is reasonable to assume that the same average would still hold. To arrive at the cost per cubic foot of triturating screenings, the maintenance cost will have to be estimated, as there has been no maintenance yet except the resharpening of one set of teeth, ten months of service and feeding to the Triturator all materials removed by the bar screen.

Re-sharpening teeth and reserve for parts replacement	$ 22.00
Water cost per year	48.87
Power cost for year	102.20
Time of operator	124.00
Depreciation at 10% per year	79.00
Total yearly cost	$375.07
Average daily cost	1.03
Total cost per cu. ft. screenings	0.08
Gross yearly cost of burying screenings	$813.00*
Gross yearly cost of triturating screenings	375.07*
Net saving by trituration (per year)	$437.93

*Including operator's time.

This means that the savings will have paid for our Triturator in less than two years' time.

Increased Gas Production

In the ten months since the Triturator was installed, gas production has averaged 7,262 cubic feet per day. The production in the corresponding preceding ten months was only 3,022 cubic feet.

When the weight of screenings is considered in relation to the total amount of settleable solids in the sewage, triturated screenings reaching the digester must be given credit for a calculated 50 per cent of the gas increase, if not more.

From this writer's experience, it can be said, with emphasis, that the successful shredding or grinding of screenings is one of the outstanding advances in sewage treatment of the past five years. No simpler disposal can be imagined than the grinding and return of all screenings to the sewage.

MODERN FINANCING OF SEWAGE WORKS*

FINANCING sewage works by revenue bonds secured by service charges is comparatively new. It is, however, a form of financing which promises wide acceptance because it is equitable and economically sound. Here are reasons why:

Sewer rental charges are small:

When billed on a monthly or quarterly basis, charges are accepted without question after the first few billings;

Delinquencies are, for the most part, negligible;

Purchasers of revenue bonds have good security.

In this booklet revenue bonds are considered as a form of municipal bond issued to construct or improve revenue-producing works when the payment of such bonds depends entirely upon the revenue from the utilities. These include sewerage systems, sewage-disposal and water works.

Although the full faith and credit of the political subdivision is not directly pledged as security for revenue bonds, the financial standing and debt history of a municipality have an important bearing upon the value of the bonds. Revenue bonds should be considered as a sound means whereby progressive municipalities may build needed improvements without disrupting other budgeted requirements and without adding anything to their general debt or tax burdens.

State and Municipal Legislation

Legislation permitting revenue bond financing of sewage works exists in 33 states. Because some of these laws were passed as emergency measures, amendments may be necessary to make the full benefits available. If enabling legislation is not adequate or is of temporary nature, it should be amended. An enabling act should provide that the department of the municipality responsible for building and operating public works may proceed with a required sewerage project upon the approval of the common council or board of trustees, and after a satisfactory ordinance has been drawn. [If the reader is interested in a typical Revenue Bond Ordinance a copy will be supplied upon request. The length of the ordinance was too great for reproduction here—

In some cities home rule charters may have to be revised to permit taking advantage of the broader scope of state legislation.

It is important that any change in state legislation or in municipal charters be suggested only after careful study of the state constitution and existing laws.

Kinds of Financing

The problem of financing sewerage facilities is of major importance to municipalities. Although most of the discussion in this booklet concerns the revenue bond method, other means are touched upon, since some cities may find them desirable. There are four principal methods for financing sewerage facilities:

1. General Tax Obligation Bonds;
2. Special Assessments;
3. Service Charge and Revenue Bonds;
4. Combination Method.

General Tax Obligation Bonds

The most used method of financing municipal improvements has been by ad valorem tax upon all real property within the municipality. Bonds have then been issued upon the basis that the improvement becomes a general obligation of the incorporated municipality. This method considers the improvement of general benefit to all property, and the tax paid by an owner to be in direct proportion to the amount of property he possesses without recognizing the utility feature of water works and sewerage.

In times of stress this method may not permit the city or town to construct or extend sewerage facilities that are vitally needed. When an improvement is most needed, the municipality may have a bonded indebtedness approximating the state constitutional or statutory limitation.

Special Assessments

The special assessment method of financing is based upon the taxing of property in proportion to the benefits bestowed. The property owner may pay his share of the cost of the undertaking outright or in a stated number of installments, usually ten. When an installment is due he receives a notice. He is expected to pay promptly what is due plus interest on the unpaid balance.

Special assessment bonds may or may not be issued, depending upon the municipality's ability to carry the cost out of other funds, or the willingness of the contractor to take assessment warrants in at least part payment.

This method of financing also leaves out of consideration payment in proportion to service rendered.

Service Charge Revenue Bonds

The revenue bond method of financing public improvements does not add to the general debt. Sewer rentals which are security for the bonds provide a means of charging the person receiving the service and in proportion to use.

The most practical method of sewer rental is a charge based on water consumption. A sewer rental schedule may be set up by ordinance for various classes of users, and users may be charged a fixed percentage of the water bill.

If for any reason it is not practicable to use water meter readings, rates can easily be adjusted to a flat rate or connection basis, depending upon the kind and size of premises occupied and the number of service connections. In any case, individual demands should be carefully studied and classified and the rates fixed accordingly. [A typical rate ordinance is given at the end of this chapter.—Editor.]

The monthly or quarterly per capita charge for the entire cost of a new sewage works plus its operating cost is generally quite small, and therefore no hardship even on the very low income group. The minimum rate at Oak Park, Illinois, for example, is $1.50 per quarter, or less than the cost of a daily paper. Of the 11,500 accounts on Oak Park's books, approximately 2,600 pay the minimum bill, and 3,600 pay the next higher rate.

Combination Financing

Sewer rentals may be charged even though the project may not be financed with revenue bonds. In some cases sewer service charges have been used merely to care for maintenance and operation. The equity of charging the user a proportion of the construction cost, however, is well recognized.

Also, sewer rentals may be used to retire general tax obligation bonds used for sewer construction. Furthermore, in ordinances establishing sewer rentals for operation and maintenance, it is usually provided that any surplus accruing from the rental collections shall be applied to the construction cost.

Where extensions or construction of waterworks are being considered with sewerage improvements, it is often advantageous to finance with combined waterworks and sewerage revenue bonds.

Sewer Rental Experience

Some fear has been expressed regarding possible delinquencies in sewer rental collections. Those who anticipate this difficulty will find that their fears have little foundation in practice. Examination of the sewer rental experience table reproduced herewith shows the small percentage of delinquencies.

In financing sewage works by the revenue bond method, questions may arise regarding the equity of the rates for sewer rentals. While the rate depends largely upon service actually used, it must be recognized that there is a definite benefit to property whether the sewer is connected or not.

An accepted principle of making a ready-to-serve or availability charge can be applied to the establishment of sewer rental rates. This principle may also be extended to cover the cost of storm sewers or, if a combined system is built, a share of the added cost.

Various methods have been used for establishing such charges. In some cases the sewer rental charge has been made to finance the construction of the treatment plant, and the cost of the collection system has been met by an entirely different method, usually some form of direct taxation or special assessment.

Where sewer rentals are to be applied to construction of both treatment plant and collection system, some municipalities have established a small ready-to-serve charge. Another and fairly general practice is to make a substantial charge for initial connection to the sewer.

(See Experience Record at end of article.)

*The material under this heading has for the most part been taken from a brochure published by the Portland Cement Association, copies of which are available upon request.

General Procedure

Carrying a sewerage project through under any kind of financing involves a number of important steps. These do not necessarily follow in order, and some of them may be taken concurrently. The principal steps are:

Make a preliminary sanitary survey;
Start a campaign to get public support;
Select a competent sanitary engineer;
Select a recognized bond attorney to prepare the bond ordinance and bond certificates;
Publish the bond ordinance;
Advertise the bond issue;
Prepare the rate schedule and publish the rate ordinance;
Prepare forms for billing the user.

Preliminary Survey

Before the need for new sewerage facilities is determined, it is desirable to have some public sentiment favorable to such improvement. The water supply may have become contaminated, and householders will start to complain of disagreeable tastes and odors. Public bathing beaches may have to be closed. Marine life may have been endangered by pollution. State health departments may have determined that a nuisance exists. All these conditions may indicate new sewage works are required, but the actual need should be established by a preliminary survey. Such a survey need not be comprehensive, but enough facts should be gathered to justify the improvement.

Securing Public Approval

Now that the municipality has decided to proceed with the construction of sanitary facilities and it has been determined that there are no legal barriers, the next logical step is to enlist widespread public support. Even though bonds may be issued without referring the matter to popular vote, the public should be informed on the urgency of the proposed construction and the entire plan of procedure.

Many city councils prefer a referendum so that there will be official record of the public's approval.

When, and if, the bond issue is to be put to a vote of the people, it is essential that the voters have full knowledge of the necessity of the project, and that they be given enough construction and operation cost information to impress them with the fact that for an exceedingly small charge they are being given an indispensable service. Many bond issues have been lost because voters gained erroneous impressions from unreliable sources.

Public approval of the proposed project should be sought through a general educational campaign, which shou'd point out:

That public health is endangered by continuation of existing conditions;

That the city may be (or has been) sued because of stream pollution and that the taxpayers will have to pay for the resulting damage;

That sound financing methods will be followed;
That costs will be reasonable;
That engineering advice and construction supervision will be competent;
That charges will be small and on the basis of use;
And further, that there will be no added tax burdens.

The whole educational program should be placed in the hands of a competent central committee. The following outline suggests major steps in an educational campaign:

A. Establish central committee
   1. Headquarters
   2. Volunteers
   3. Appoint publicity director
B. Report on investigations
   1. Engineer's report
   2. Financing methods (advice obtained from bond attorneys)
   3. Comparable conditions in other cities
      How remedied?
C. Publicity
   1. Newspaper articles
      Full details given to press; cooperation obtained in interest of public welfare
   2. Advertisements—if election to be held, present final conclusive arguments immediately preceding election day
   3. Booklets and pamphlets —simple, direct statements
D. Canvassing
   1. Individual calls by volunteers
   2. Endorsements by prominent citizens.
E. Local organizations
   1. Obtain support of local groups
      Business
      Professional
      Chambers of commerce
      Women's organizations
      Civic clubs
      Schools, etc.
F. Lectures and radio talks
   1. By city officials
      Engineers
      Attorneys
      Volunteer citizens
G. Displays
   1. Posters in store windows
   2. Posters in homes

Selecting the Consulting Sanitary Engineer

The job of building modern sewage works requires highly specialized ability, and should be entrusted only to a competent sanitary engineer.

Although the sanitary engineer will know what facts he will have to gather, others not technically trained will be interested in a brief picture of the scope of his necessary investigations, which are as follows:

Source and quality of water supply.

Stream-gage measurements, particularly low-water and flood stages, if the water supply is taken from a river or the sewage effluent is to be diverted to a river or stream.

Population characteristics, with particular reference to population stability, proportions in various income groups, whether population is increasing or decreasing, etc.

Land use characteristics of the area. It should be known what proportion of the area to be served is industrial; how much is commercial and how much residential, with these areas located with respect to municipal corporate limits or sanitary district limits; and the recreational facilities of the community, etc.

Physical characteristics of the area. Obviously, a physical survey will have to be made to determine where the plant is to be built to take full advantage of gravity flow of sewage, to determine if any pumping will be necessary, and to solve other problems concerned with actual design.

The number of water connections in the area to be served by sewerage facilities, and the probabilities of increase. Adequacy of existing water supply and probable reasonable increase also will be established. It should certainly be known how many sewer connections exist and whether the connections are industrial, commercial or residential.

Method of garbage collection and disposal.

These are a few of the many important things the sanitary engineer will investigate.

Selecting Bond Attorney

A recognized bond attorney should be consulted at the outset. In cooperation with the city attorney, the bond specialist will prepare and approve the necessary ordinances and form of bond proposal.

This procedure not only protects the city against legal faults, but it helps materially in selling the bonds. An opinion of a recognized bond attorney will be necessary before the bonds are delivered, but a preliminary opinion is desirable, as it obviates subsequent delay. Also, if bond purchasers know that all details have been handled or approved by bond specialists, the bonds will be regarded much more favorably.

Publishing Bond Ordinance

As soon as the bond attorney and the city attorney have drafted the bond ordinance, the city council should pass the ordinance and publish it. The way is then clear for financing the project.

Advertising Bond Issue

City officials will find helpful suggestions regarding the bond advertisement in a municipal circular issued by the Investment Bankers Association of America. These suggestions, embodied in Recommendation No. 19, are:

"19. SPECIAL REVENUE BONDS:

"Reference is made to a resolution adopted by the Board of Governors on May 11, 1937, that part of which outlining specifications is as follows:

" 'That advertisements or circulars describing revenue bonds shall clearly indicate the nature of the obligation.

" 'That the customary form of the ordinary municipal circular and advertisement be varied to prevent confusion in the mind of the casual or careless reader.

" 'That the type of obligation be clearly described in the caption, and with prominence consistent with that accorded to the name of the municipality.

" 'That priority of obligation, if any, be stated specifically.

" 'That the statement of assessed valuation, total debt, etc.,

if included, be given a secondary rather than a primary position.

"'That in connection with such statement of assessed valuation, etc., a statement shall be made, and prominently displayed, to the effect that the assessed valuation reported is not subject to taxation for the payment of principal and interest on the bonds.'"

Bonds may be offered for sale as soon after the issue has been advertised as seems convenient or advisable. The services of some financial specialist may be secured to advise the city officials when the bonds may be most advantageously sold and in what amounts.

Establishing Rate Schedule

An equitable rate schedule is fundamental to successful financing of sewerage facilities by the revenue bond method. Obviously, then, care must be exercised in adjusting the schedule to the kind and amount of service rendered.

The recommendations of the sanitary engineer should be sought in establishing the rates. He will view the proposed schedule from the standpoint of existing earning capacity plus reasonable future increases. It cannot be emphasized too strongly that an adequate and equitable rate schedule will enhance the possibilities for advantageous sale of the bonds. An inadequate schedule may jeopardize the entire program. Raising deficient rates is far more difficult than lowering rates found to yield more revenue than is currently required.

Preparing Billing Forms

Municipalities have worked out ingenious methods of billing to meet their particular requirements. A simple statement showing separately the amounts charged for water and for sewerage service is generally preferred, however. Where possible, the billing and collection of sewerage charges can be made by the same staff and at the same time as the water bills. This has been done by several cities at almost no increase in collection costs.

It is especially desirable that bills be rendered monthly or quarterly. An annual charge for a new municipal service, however reasonable, may appear exorbitant to the payer.

Two single billing forms are reproduced on the next page.

Typical Sewer Rental Ordinance

AN ORDINANCE

FIXING THE RATES TO BE CHARGED BY THE CITY OF DAYTON, OHIO, TO THE OWNERS OF BENEFITED PROPERTY FOR THE USE OF ITS SANITARY SEWERAGE SYSTEM, OF PARTS SANITARY SEWERAGE SYSTEM AND TREATMENT WORKS.

WHEREAS, . . . THEREFORE,

BE IT ORDAINED BY THE COMMISSION OF THE CITY OF DAYTON:

Section 1. It is hereby determined and declared to be necessary and conducive to the protection of the public health, safety, welfare and convenience of the City of Dayton, Ohio, to levy and collect charges or rentals upon all lots, lands, and premises served by having connections with the sanitary sewerage system and by the sewage pumping, treatment and disposal works of said City, the proceeds of such charges or rentals so derived to be for the use of the sanitary sewerage system and the pumping, treatment and disposal works of said city, as hereinafter provided.

Section 2. (Defines "Sanitary Sewage" and "Industrial Wastes."—Editor).

Section 3. For the purposes as provided in Sections 1 and 8 hereof there is hereby levied and assessed upon each lot, parcel of land, building or premises having any sewer connection with the sanitary sewerage system of said city or otherwise discharging sewage, industrial wastes, water or other liquids, either directly or indirectly into the City sanitary sewerage systems, a sewerage service charge or rental payable as hereinafter provided, and in amount determinable as follows:

(a) For any lot, parcel of land, building or premises situated within the corporate limits of the City of Dayton, Ohio, and having any connection with the city sanitary sewerage system or otherwise discharging sanitary sewage, industrial wastes, water or other liquids, either directly or indirectly, into the City sanitary sewerage system, said charge or rental shall be based upon the quantity of water used thereon or therein as the same is measured by the City water meter there in use, and there shall be charged: for the first 3000 cubic feet of water, or part thereof, so used per quarter year, the sum of One Dollar ($1.00); for each thousand cubic feet of water used in excess of 3000 cubic feet and not exceeding 10,000 cubic feet, per quarter year, at the rate of Thirty Cents (30c) per 1000 cubic feet; for each thousand cubic feet of water in excess of 10,000 cubic feet and not in excess of 20,000 cubic feet, per quarter year, at the rate of Twenty-five Cents (25c) per 1000 cubic feet; for each thousand cubic feet of water in excess of 20,000 cubic feet and not in excess of 100,000 cubic feet per quarter year, at the rate of Twenty Cents (20c) per 1000 cubic feet; for each thousand cubic feet in excess of 100,000 cubic feet and not in excess of 500,000 cubic feet per quarter at the rate of Fifteen Cents (15c) per one thousand cubic feet; for each thousand cubic feet in excess of 500,000 cubic feet per quarter at the rate of ten cents (10c) per 1000 cubic feet; provided, that the minimum charge shall be One Dollar ($1.00) per quarter year or part thereof.

(b) For any lot, parcel of land, building or premises situated outside of the corporate limits of the City of Dayton, Ohio, and having any connection with the city sanitary sewerage system or otherwise discharging sanitary sewage, industrial wastes, water or other liquids, either driectly or indirectly, into the city sanitary sewerage system, said charge shall be based upon the quantity of water used thereon or therein as the same is measured by a water meter there in use which meter shall be to the approval of the Director of Water, and there shall be charged for the first 3000 cubic feet of water, or part thereof, so used per quarter year, the sum of One Dollar and Twenty-five cents ($1.25); for each thousand cubic feet of water used in excess of 3000 cubic feet and not exceeding 10,000 cubic feet, per quarter year, at the rate of Thirty-eight cents (38c) per thousand cubic feet; for each thousand cubic feet of water in excess of 10,000 cubic feet and not exceeding 20,000 cubic feet per quarter year at the rate of Thirty-one cents (31c) per thousand cubic feet; for each thousand cubic feet of water in excess of 20,000 cubic feet and not exceeding 100,000 cubic feet per quarter at the rate of twenty-five cents (25c) per thousand cubic feet; for each thousand cubic feet in excess of 100,000 cubic feet and not in excess of 500,000 cubic feet per quarter, at the rate of nineteen cents (19c) per thousand cubic feet; for each thousand cubic feet in excess of 500,000 cubic feet per quarter at the rate of thirteen cents (13c) per thousand cubic feet; provided that the minimum charge shall be One Dollar and Twenty-five cents ($1.25) per quarter year or part thereof.

(c) In the event a lot, parcel of land, building or premises discharging sanitary sewage, industrial waste, water or other liquids into the City sanitary sewerage system, either directly or indirectly, is not a user of water supplied by the Department of Water of said City and the water used thereon or therein is not measured by a city water meter, or by a meter acceptable to the Director of Water, then, in each such case the amount of water so used shall be otherwise measured or determined by the Director of Water in order to determine the sewer service charge or rental provided in this ordinance, or the owner or other interested party at his expense may install and maintain a meter acceptable to the Director of Water for said purpose.

(d) In case a lot, parcel of land, building or premises discharges industrial wastes, either directly or indirectly, into the City sanitary sewerage system, and the Director of Water finds that it is not practical to attempt to measure such wastes by meter, he shall measure such wastes in such manner and by such method as he may find practicable in the light of the conditions and attendant circumstances of the case, in order to determine the sewer service charge or rental, according to the corresponding rates per thousand cubic feet provided in this ordinance.

(e) A discount of five (5) per cent shall be allowed for prompt payment.

In addition to the charge or rental determined according to the rates specified herein a further charge of five (5) per cent of such amount so determined shall be added thereto in each case of failure to make prompt payment, and the total thus obtained shall be the sewerage service charge or rental in each such case.

("Prompt Payment" defined.—Editor.)

(f) The sewer service charge or rental provided in this ordinance shall be payable quarterly at the office of the Department of Water, and, at the option of the Director of Water may be made payable at the same time as water bills in the district in which the property is located are payable.

(g) (Exempts City, County, State, and Federal property except specified institutions.—Editor.)

Section 4. For any lot, land, building or premises from which connection is made with the City sanitary sewerage system or which begins to discharge sewage, any industrial waste, water or other liquids into the City sanitary sewerage system, either directly or indirectly, after this ordinance becomes effective, a charge shall be made pursuant to this ordinance, the same to be a

per diem pro rata amount based upon the minimum rate per quarter from the time such sewer connection is made, or such discharge into the City sewerage system, either directly or indirectly, is begun, until the next following quarter period, except should the measured service exceed the minimum charge the corresponding measured rate or rates shall be charged.

Section 5. The charge or rental levied and assessed by this ordinance shall be payable in four quarterly payments in each year, as provided in Section 3, paragraph (f), hereof, provided that the amount of the rental payable for any lot or premises at the first payment period after this ordinance becomes effective shall be determined on the basis of a per diem pro ratement or the minimum charge herein established beginning with the date this ordinance becomes effective, except that in those cases in which the metered or measured charge will exceed the minimum charge, the metered or measured charge shall be the basis.

Section 6. Each charge or rental levied by or pursuant to this ordinance is hereby made a lien upon the corresponding lot, land or premises served by a connection to the sanitary sewerage system of the City of Dayton, Ohio, and if the same is not paid within thirty (30) days after it shall be due and payable it shall be certified to the Auditor of Montgomery County, Ohio, who shall place the same on the tax duplicate of said county with the interest and penalties allowed by law and be collected as other taxes are collected.

Section 7. The charges or rentals levied pursuant to this ordinance shall be collected by the Department of Water, and the Director of said Department shall make and enforce such by-laws and regulations as may be deemed necessary for the safe, economical and efficient management and protection of the City sewerage system and the sewage pumping, treatment and disposal works, for the construction and use of house sewers and connections to the sewerage system, and for the regulation, collection, rebating and refunding such charges or rentals.

Section 8. The funds received from the collection of the charges or rentals authorized by this ordinance shall be deposited daily with the City Treasury and shall be accounted for and be known as the Sanitary Sewer Fund, and when appropriated by the City Commission, shall be available for the payment of the cost and expense of the management, maintenance and repair of the City sanitary sewerage system and the sewage pumping, treatment and disposal works, and any surplus in such fund shall be used for the payment of the interest on bonds issued and outstanding or which may be issued to provide funds with which to pay the City's portion of the cost of constructing such sanitary sewerage system, or part thereof, and such sewage pumping, treatment and disposal works and to retire such bonds when they mature, and/or for the enlargement or replacement of said sanitary sewerage system, pumping, treatment and disposal works, except that no part thereof shall be used for the extension of such sewerage system into unsewered areas.

Passed by the Commission December 28, 1927.

Typical Billing Forms

The billing side of the Oshkosh, Wisconsin, form at right is in three sections, the sewer rental rates being shown on the reverse side.

The billing form below is used by the City of Lebanon, Illinois

CITY OF OSHKOSH—SEWERAGE COMMISSION
ROOM 16—CITY HALL TELEPHONE 600

SEWERAGE SERVICE FOR QUARTER ENDING SEPTEMBER 30, 1938

BALANCE

FIXED CHARGE ($1.60 PER YEAR) 40

SERVICE CHARGE BASED ON { METERED WATER / UNMETERED WATER

TOTAL

THIS BILL MUST BE PAID WITHIN 15 DAYS. BRING BILL WITH YOU.
(RATE INFORMATION ON BACK)

CITY OF OSHKOSH—SEWERAGE COMMISSION
SEPTEMBER 30, 1938

BALANCE

FIXED CHARGE 40

SERVICE CHARGE: { METERED WATER / UNMETERED WATER

TOTAL

SEND THIS STUB WITH MAIL REMITTANCE

OFFICE COPY
SEPTEMBER 30, 1938

BALANCE

FIXED CHARGE 40

SERVICE CHARGE: { METERED WATER / UNMETERED WATER

TOTAL

PAID

BAL.

CITY OF OSHKOSH — SEWERAGE COMMISSION
SEWER RENTAL RATES

Annual fixed or basic charge for each connection to sewer system—$1.60 per year (40c per quarter).

Service charges for users of city water are 50% of the consumption charge or minimum charge for water furnished the user. In determining this charge for residences, the average of the water bills rendered on the first days of April and July of each year is obtained and 50% of that average is the service charge for each of the four quarters of the year. This method is followed so as to eliminate sewer charges on water used during the summer months for sprinkling lawns and watering gardens, and applies to residences only. In cases where this average cannot be obtained because of change in occupancy or for other reasons, the actual water consumption is the basis for determining the sewer charge.

FOLIO..... ACCT. NO.....

NAME .....

STREET .....

TOTAL GAL. WATER CONSUMED - .....

DEDUCTIONS, IF ANY - - - - - .....

TOTAL GAL. TO BE CHARGED - .....

MINIMUM CHARGE PER QUARTER

AMOUNT - - - - - - - - - $

NO. OF DOWNSPOUTS AT 25C EACH PER MONTH

TOTAL - - - - - - - - - $

FORM 27

TO CITY OF LEBANON DR., ACCT. NO. .....

CARD NO. .....

FOR WATER AND SEWAGE DISCHARGED INTO THE SANITARY SEWER

RECEIVED OF..... DATE..... TO..... 195...

STREET NO.....

OUT LOT	BLOCK	LOT NO.	ADDITION

TOTAL GAL. WATER CONSUMED.....

DEDUCTIONS, IF ANY - - - .....

TOTAL GAL. TO BE CHARGED - .....

..... GAL. AT 12C M $

..... GAL. AT 10C M

..... GAL. AT 9C M

..... GAL. AT 8C M

..... GAL. AT 7C M

..... GAL. AT 6C M

MINIMUM CHARGE PER QUARTER - - -

AMOUNT - - - - - - - $

NO. OF DOWNSPOUTS AT 25C EA. PER MO.

TOTAL - - - - - - - - $

SEWER RENTAL EXPERIENCE

STATE & CITY	POPULATION	FINANCED WITH REVENUE BONDS	RATE BASIS: WATER CONSUMPTION	RATE BASIS: OTHER METHODS	BILLING METHODS: MONTHLY	BILLING METHODS: QUARTERLY	DELINQUENCIES	REMARKS ON COLLECTIONS
ARKANSAS								
Batesville	4,500	Yes		Flat rate	Yes			Citizens protest.
Brinkley	3,046	Yes		Flat rate	Yes			
Fordyce		Yes		Flat rate	Yes			Some difficulty due to protests.
Little Rock	80,000	Yes	Yes		Yes		6 to 8%	Some protest from tenants.
Stuttgart		Yes		No. of connections				
Waldron		Yes		Varies with service				Very little difficulty.
West Memphis	2,900	Yes		No. of fixtures	Yes		Negligible	Few protests.
FLORIDA								
Ft. Lauderdale	(Max.) 40,000	Yes	Yes		Large meters	Small meters	Less than 5%	
Tallahassee	15,000	No		No. of fixtures	Yes		0	A few protests on first bill.
GEORGIA								
Athens	22,000	No		No. of fixtures			5%	
ILLINOIS								
Anna	4,000	Yes		No. of connections		Yes	0	
Barrington	4,000	Yes	Yes			Yes	4½%	Few protests.
Belvidere	9,123	Yes	Yes			Yes	5%	
Edwardsville	6,500	Yes	Yes	Also flat rate	Yes		15%	Object to not having referendum
Effingham	5,301	Yes		No. of connections		Yes	10%	
Elmhurst	15,000	Yes	Com'l.	Flat rate residences	Yes		½%	
Kankakee	22,300	Yes		No. of fixtures	Yes (also bi-monthly)		6%	No unusual difficulties.
Kewanee	17,000	Yes	Yes				12%	No difficulties.
Libertyville	4,000	Yes	Yes			Yes	½%	
Monmouth	9,000	Yes	Yes		Yes		10%	
Rochelle	3,890	Yes	Yes			Yes		No difficulties.
Sullivan	3,300	Yes	Yes		Yes		¼%	No difficulties.
Waterloo	2,300	Yes		Flat rate	Yes		Very small	
West Chicago	3,900	Yes	Water & sewer combined			Yes	5%	
West Dundee	1,800	Yes		Flat rate		Yes	1%	Few mild protests.
INDIANA								
Bloomington	18,227	Yes	Yes (discharges into sewer)		Yes		1%	No difficulty.
Goshen	12,000	Yes	Yes (plus flat rate & connect. chg.)		Yes		10%	No difficulty.
Kokomo	32,843	Yes	Yes	Also flat rate	Yes		7%	Some objections at first—
La Porte	16,000	Yes	Yes	Flat rate	Large users	Small users	10%	none now.
Michigan City	30,000	Yes	Yes	Flat rate	Yes		10%	Very little difficulty.
Mitchell	3,228	Yes	Yes				0	
IOWA								
Cedar Rapids	60,000	Yes	Yes		Yes (also bi-monthly)		Very small	No difficulty.
Ft. Dodge	25,000	No	Yes			Yes		
Iowa City	15,340	Yes	Yes		Yes			Some protests.
Mt. Vernon	1,500	Yes	Yes			Yes		
KENTUCKY								
Beaver Dam	1,050	No		No. of fixtures	Yes		0	
Providence	5,000	Yes	Yes		Yes		8%	Slight difficulty with some.
Richmond	7,500	Partly	Yes	Also flat rate	Metered	Flat rate	0	Some objections to rate.
LOUISIANA								
Jennings	6,500	No		Flat rate on water bill	Yes		2%	
MICHIGAN								
Ann Arbor	30,000	Yes	Yes		Partly	Yes	Less than 1%	No difficulty.
Battle Creek	45,000	Partly	Yes		Yes		4 to 6%	Some complaints.
Grand Haven	8,345	Yes	Yes		Yes		4%	
Jackson	55,000	Yes	Yes (based on winter months)		Yes			No difficulty.
Traverse City	13,000	No	Yes			Yes	5%	Difficulty at first only.
NEBRASKA								
Adams	535	No		Flat rate	Yes			
Blue Hill	669	No		Flat rate	Yes			
Columbus	6,000	Yes		Flat rate		Yes	Less than 1%	
Lawrence	528	No		Flat rate	Yes			
Peru	835	Yes		Flat rate	Yes			
Trenton	865	Yes		Flat rate	Yes			
NEW YORK				Balance charged				
Buffalo	583,000	Yes	Yes (55%)	against real property	Monthly, quarterly & semi-annually			
Plattsburgh	13,347	Yes		Flat rate and no. of connections				
OHIO								
Bedford	7,400	No	Yes			Yes		
Berea	5,697	No	Yes			Yes		
Bowling Green	6,688	No		Flat rate		Yes	Negligible	
Dayton	200,982	Partly	Yes (Modified)			Yes		
Findlay	19,363	Partly	Yes		Yes		8%	No serious difficulty.
Greenville	7,036	Partly	Yes			Yes	None	No difficulty.
Mansfield	33,525	No	Yes			Semi-annually	5%	A few protests at first.
Oxford	2,588	Yes	Yes			Yes		
Springfield	68,763	No	Yes			Semi-annually		
Toledo	290,718	No	Yes			Yes	20% but will be collected: loss not more than .03%	
PENNSYLVANIA								
Abington Township	18,500			No. of fixtures			None	
Cheltenham Township	18,200	No		No. of fixtures		Annually	Small	
Haverford Township	25,000	No		No. of fixtures		Annually	Few	
Jenkintown	5,000					Annually	Small	
Media	5,000	No	Yes	Also no. of connect'ns		Annually	5%	
Radnor Township	12,317			No. of fixtures		Annually	Small	
Springfield Township	5,000			No. of fixtures		Annually	Few	
U. Moreland Township	4,500	Partly				Annually	10%	
TENNESSEE								
Lawrenceburg	3,500	Yes		Flat rate	Yes		None	
Parsons	1,000	Yes		Flat rate	Yes		None	
TEXAS								
Alvin		No		Flat rate	Yes		5%	No difficulties.
Big Spring	15,500	No		Flat rate	Yes			
Brownsville	25,000	No		No. of connections	Yes		1%	Only few protests.
Corpus Christi	56,000	Yes	Yes (with		Yes		2%	Some difficulty because no
El Paso	102,000	Yes	min. charge)	Flat rate			None	deposit required.
Jasper	4,500	No		Flat rate	Yes		5%	
La Feria	1,600	No		No. of connections	Yes		10%	No protests.
Lufkin	10,000	No		No. of fixtures		Yes	None	
Mineral Wells	7,000	No		No. of fixtures	Yes		10%	
Raymondville	3,800	No		Flat rate & fixtures	Yes		30%	Owners and renters disagree on
Snyder	4,000	No		Connections & fixt.	Yes		None	who should pay.
Sweetwater	15,000			Fixtures	Yes		None	
Wharton	3,600		Yes	Minimum & fixtures	Yes		None	
VIRGINIA								
Berryville	1,200	Yes		Flat rate		Semi-annually	10%	
Christiansburg	2,000	No		Flat rate	Yes		4%	
Herndon	1,000	Partly		Flat rate		Yes		
Roanoke San. Dist.	6,000	Yes		Flat rate		Yes	None	
Williamsburg	3,778	No		Flat rate		Yes	4%	
Winchester	12,500	No		Flat rate		Annually	1%	
WISCONSIN								
Oshkosh	40,108	Mostly	Yes	Flat rate		Yes		

(We recommend to the reader the 120-page brochure "Sewer Rentals," recently published by the American Public Works Association, 1113 East 60th St., Chicago.—Cost to non-members, $1.50.—Ed:)

THE JEFFREY MANUFACTURING COMPANY

SANITARY ENGINEERING DIVISION

996-99 North Fourth Street, Columbus, Ohio

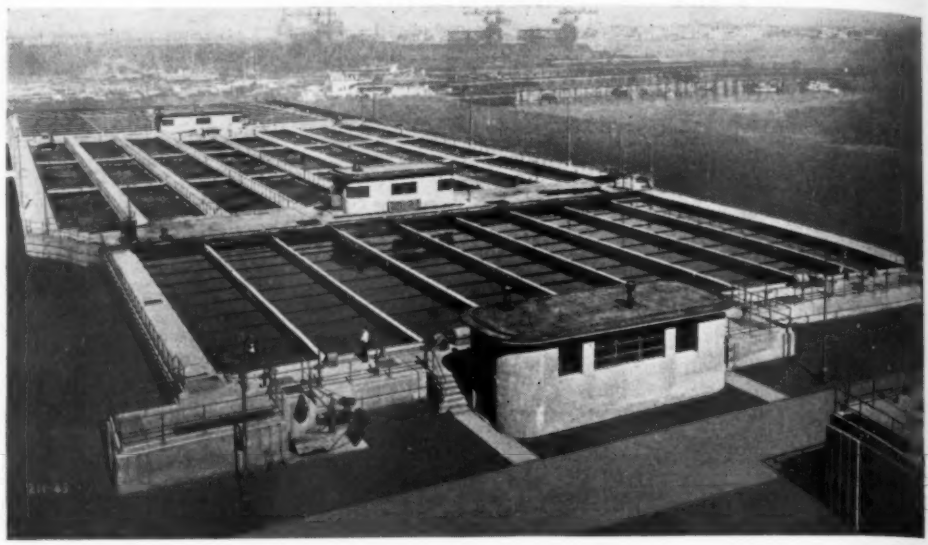
Established in 1877

Baltimore, Birmingham, Boston, Buffalo, Chicago, Cincinnati, Cleveland, Denver, Detroit, Harlan, Houston, Huntington, Milwaukee, New York, Philadelphia, Pittsburgh, Scranton, St. Louis, Salt Lake City

Jeffrey Mfg. Co., Ltd. of Canada—Head Office and Works: Montreal

PRODUCTS:

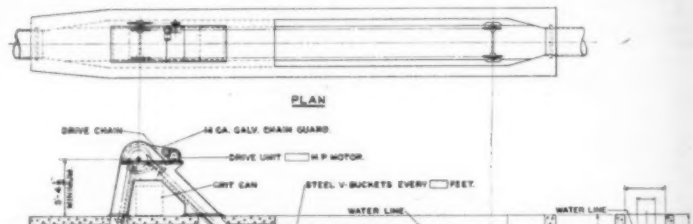
- **Bar and Disc Screens**
- **Chains**
- **Conveying and Elevating Equipment**
- **Dried Sludge Grinders**
- **Feeders (chemicals)**
- **Floctrols**
- **Grit Collectors**
- **Grit Washers**
- **Garbage Grinders**
- **Scum Collectors**
- **Screenings Grinders**
- **Sludge Collectors**
- **Sludge Elevators**
- **Sprockets**
- **Transmission Machinery**

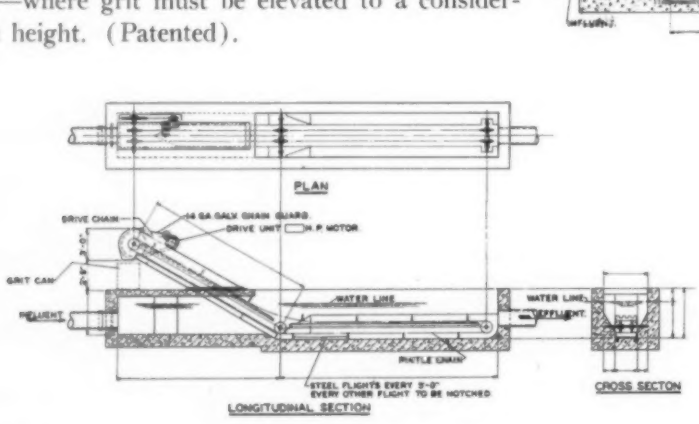


Typical installation (above) of a Jeffrey sewage treatment plant showing rectangular tank design. Jeffrey collectors will remove sewage sludge effectively and economically.

GRIT COLLECTORS

Three types for grit channel mechanism: scraper, V-bucket and a combination of the two. The scraper type is shown in drawing below—it continues up the incline. V-bucket type with horizontal and vertical runs is shown in drawing at the right. Latter type is ideal where space is limited—where grit must be elevated to a considerable height. (Patented).

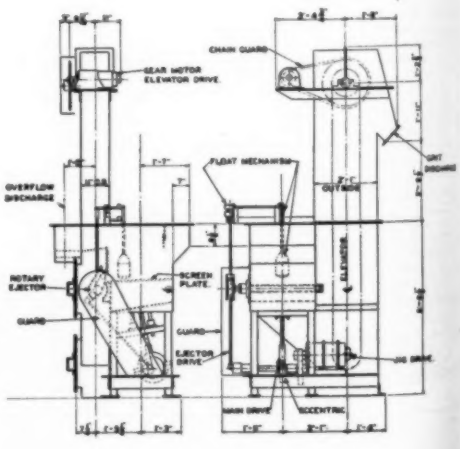




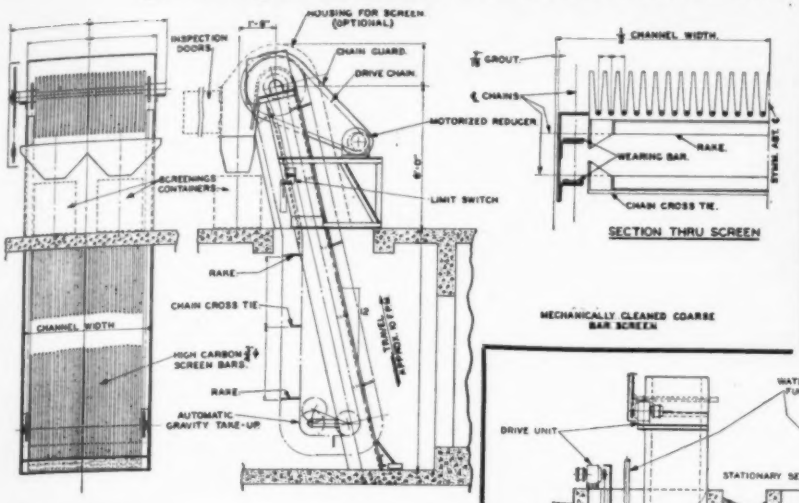
Send for Catalog No. 775-E

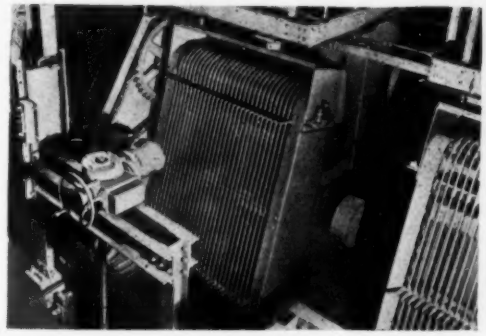
GRIT WASHERS

Proved method of washing grit—Jeffrey JIGRIT. Will remove from 80 to 90% of putrescible solids, the washed grit being free from objectionable odors or unsightly appearance. Two sizes with capacities from 1 ton to 4 tons per hour. Drawing (right) is of the Jeffrey No. 4 JIGRIT. Full automatic controls. (Patented.)



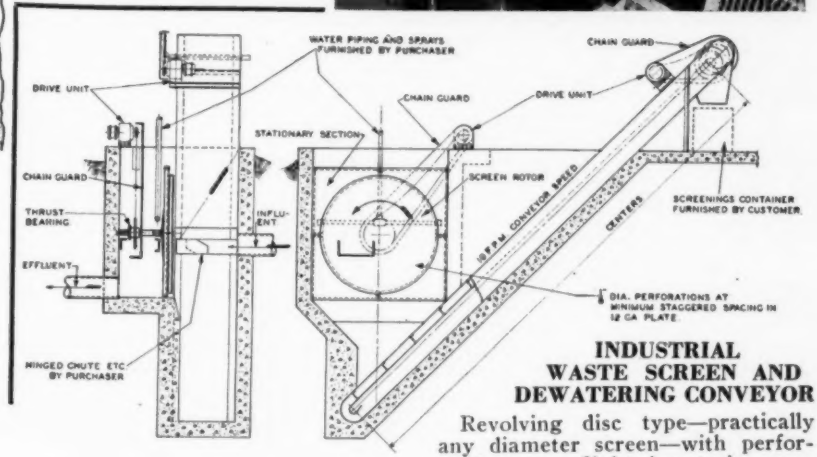
THE JEFFREY MANUFACTURING COMPANY





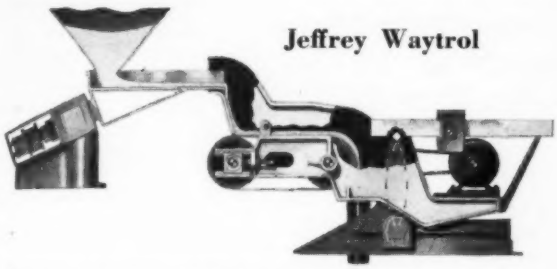
BAR SCREENS

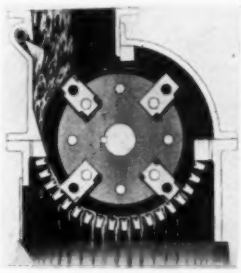
Mechanically cleaned — practically foolproof — no jamming at bottom since the rakes, entering the bars from discharge side, lift screenings off as rakes enter bars. Time or float control operation. Used in combination with a Jeffrey Screenings Grinder, screenings are collected and reduced for returning to sewage.



INDUSTRIAL WASTE SCREEN AND DEWATERING CONVEYOR

Revolving disc type—practically any diameter screen—with perforated scraper flight dewatering conveyor (Pats. Pending). Inclined deck above water line also perforated for dewatering screenings. See drawing above.



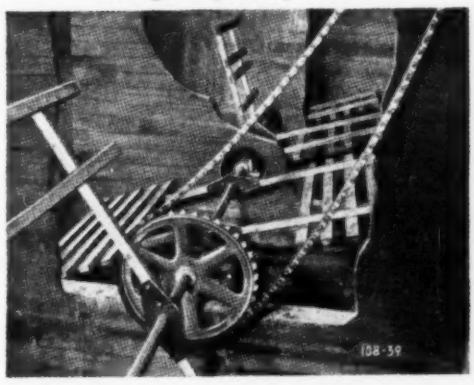


GRINDERS

Disposal of screenings by grinding most satisfactory method. We recommend hand-feeding to Jeffrey grinders, which are built in wide range of sizes for practically any capacity. Ground to a pulp, the screenings will settle out with the sludge in primary tanks.

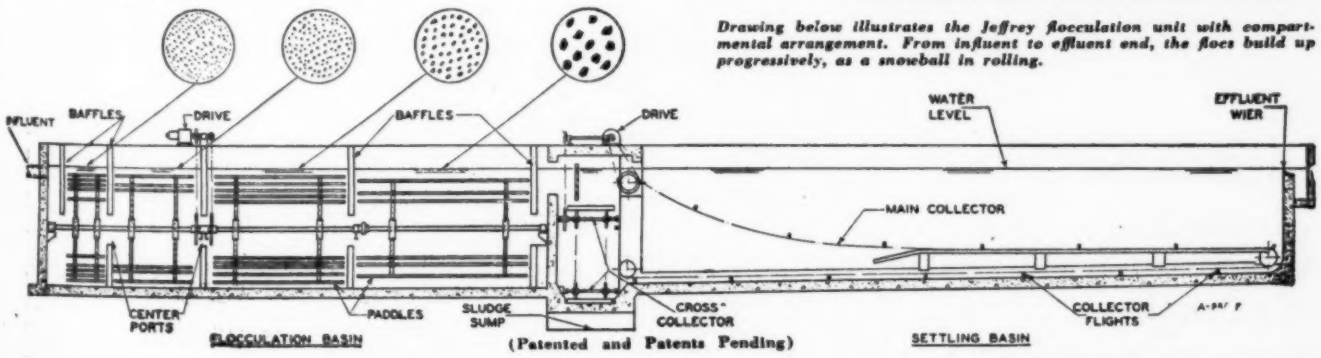
ACCURATE GRAVIMETRIC FEEDER

Continuous and accurate weigh-feeding of dry chemicals assured with the Jeffrey Waytrol—features shown in above drawing. This unit will feed and weigh to 1% of required amount—rate of feed can be varied over a wide range by merely turning a knob. Feeder will automatically maintain given rate, regardless of density or moisture change. (Patented).



JEFFREY "FLOCTROL"—a new process for pre-clarification of turbid waters. While using a minimum of chemical coagulant, it conditions water to obtain substantially complete removal of solids in sedimentation basin. Can be used for treating sewage and waste water, water softening and industrial processing. Low first cost—minimum of short circuiting—low chemical cost—tapered mixing—no mechanical adjustments. (Patented).

Drawing below illustrates the Jeffrey flocculation unit with compartmental arrangement. From influent to effluent end, the floes build up progressively, as a snowball in rolling.



(Patented and Patents Pending)

SEWAGE TREATMENT PLANT OPERATION

Compiled from Various Sources

By A. P. BANTA

Asst. Engr., Los Angeles County Sanitation Districts, and
Asst. Prof. San. Eng., California Inst. of Technology
Pasadena, California

A DAILY inspection of each major unit of the plant by the plant operator should be made, any unusual conditions recorded, and faulty conditions immediately remedied. The plant operating data should be fully compiled each day, and kept, as an aid in maintaining the plant in proper operating condition. Such records are valuable for future reference and as evidence.

It is especially important that the daily flow or rate of flow of sewage reaching the plant be measured and recorded. Methods commonly employed to determine sewage flow are as follows:

1. Weir measurements.
2. Counters on dosing tanks of known capacity.
3. Capacity of pumps and period of operation.
4. Recording meters (Venturi, weir, etc.).
5. Dosing tank period for filling.

Records of power consumption and supplies, tools or chemicals obtained should be maintained. A daily log book for keeping such records and information concerning general or unusual conditions is very useful.

The air temperature, wind direction and general weather conditions should be recorded daily. This information is valuable in the investigation of nuisance complaints such as odors.

It is also essential that a few simple tests be made to determine the efficiency of separate units of the plant or of the plant as a whole. The results of these tests and a record on operation will:

1. Indicate to the operator whether the plant is or is not functioning properly.
2. Aid the municipality or institution in case of law suits resulting from alleged pollution or nuisance.
3. Assist consulting engineers in planning changes or additions to the plant.
4. Enable the officials responsible for the operation of the sewage disposal plant to prepare reports to the public and to the State Department of Health on the operation and efficiency of the plant.

The operator should have for ready reference plans or blue print designs of the plant, showing the dimensions of each unit and all pipes, valves, gates, etc., in order that he may be able to fully understand the construction and operating details of the plant.

A competent sanitary engineer can materially improve operating conditions through guidance and advice. It would be advisable for municipal or other officials to retain consulting engineers, or an experienced operator from a nearby plant, for a few years after completion of a new plant in order to supervise plant operation. Operating difficulties may frequently be prevented or readily corrected by following their advice.

Operators of sewage treatment plants should always remember that sewage gases are combustible and also explosive under certain conditions. Such gases may be toxic and asphyxiating. It is, therefore, necessary to take unusual precautions where such gas may be present either in the sewer system or at the treatment plant. No open flames or other sources of ignition should be permitted. Adequate ventilation of manholes and other similar enclosures before entering is always advisable. Moreover, no one should ever enter a place where such gases are likely to be present without an emergency rope attached to his person and two watchful attendants stationed outside. When the gases are toxis, i. e., containing poisonous gases, a special gas mask should also be used.

The following are a few fundamental details of the proper operation of sewage treatment plants. Local conditions may alter somewhat the following operating details but in general these notes give a resume of the operating procedure for the various types of treatment described.

Grit Chambers

1. Grit chambers should be cleaned after every large storm.
2. Grit chambers should be cleaned whenever tests show that the grit compartment (the compartment below the inverts of entering and outlet channels) is filled with hard material to 50 or 60 per cent of its capacity.
3. The grit should be promptly disposed of by burying it or drying it on sludge beds. If it is sufficiently clean, it may be used for filling in low land.

Coarse Screens (½-Inch to 3-Inch Openings)

Screenings, unless properly disposed of, are frequently a serious source of nuisance at a treatment plant because they decompose readily, giving off obnoxious odors. They will also encourage the breeding of rats and flies unless properly cared for. Furthermore they are unsightly and repulsive to visitors.

1. Remove the screenings twice daily or oftener if necessary to prevent clogging of the screen and consequent backing up of sewage in the outfall sewer.
2. Promptly dispose of screenings by:
   (a) Burial, covering by at least 12 inches of earth, either by ploughing under the soil or shallow trenching. They may be placed in trenches, treated with borax, chloride of lime, or other disinfectant and covered with earth as early as possible.
   (b) Incineration where possible.
   (c) Grinding, either returning ground material to the sewage flow or mixing it with the primary tank sludge going into digesters.
3. Clean the screen chamber, removing all accumulated sludge and grease, at least once a day.

Fine Screens (½-Inch or Less)

1. Fine screens are usually continuously mechanically cleaned, either by water, air or revolving brushes, and therefore all moving parts should be properly lubricated to keep them in proper working condition.
2. Remove and dispose of screenings promptly by:
   (a) Mixing with garbage and incinerated.
   (b) Dewatering by pressing, and then incinerating or burying the solids.
   (c) Burial, covering by at least 12 inches of earth, either by ploughing under the soil or shallow trenching. They may be placed in trenches, treated with chloride of lime, or other disinfectant, and covered with earth as early as possible.
   (d) Digested with other solids removed by sedimentation

Septic Tanks

1. Sludge and scum should be removed whenever they accumulate to a combined depth equal to ¼ the depth of the tank below the flow line.
2. Sludge should be removed when large suspended particles are observed in the effluent, or when the daily test of settleable solids in the Imhoff cones shows any appreciable increase of settleable solids in the effluent.
3. All inlet and outlet channels, pipes, weirs, valves, etc. should be kept clean and free from accumulations of grease and grit.

Mechanically Cleaned and Plain Settling Tanks with Separate Sludge Digestion

(A) Plain Settling Tanks:

1. The settled solids should be completely removed at frequent intervals, at least twice daily, from the settling tanks to the separate sludge digestion tanks. Mechanical equipment installed for the collection of sludge should be operated for a sufficient length of time before drawing sludge to insure complete removal of the deposited solids.
2. Septic action in the plain settling tanks as evidenced by "gassing" or rising sludge or an appreciable increase of settleable solids in the settling tank effluent should be avoided by prompt and regular removal of sludge to the digestion tanks.

3. Grease and scum should be removed at least daily, using the mechanical skimming device or by using a perforated hand-skimmer and the tanks should be maintained in a clean appearing condition at all times.

(B) Separate Sludge Digestion Tanks:

1. The contents of single tanks should be stirred or agitated at intervals by recirculation or other means to assure proper "seeding" of the fresh solids and to afford rapid and efficient digestion. Such stirring also lessens the chance of acid production, "foaming" difficulties, and excessive scum formation. Where there is surplus capacity or stage digestion this operation is of doubtful benefit.
2. Where heating coils or other adequate means of heating the contents are available, the temperature should be maintained at about 85° F.
3. The amount of fresh solids added daily should not be over one twentieth (5%) of the amount of "ripe" sludge in the tank, on the basis of the dry solid content of each.
4. Care must be used in removing digested sludge to avoid the removal of such a large amount that the ratio of "ripe" sludge to fresh sludge added drops below twenty to one.
5. By concentration tanks or otherwise the solids content of the sludge added to digesters should be as high as is practical to avoid loading the digesters with liquid which reduces the time of the solids in the digesters, creates undue disturbance and chills the contents. This matter is far more important than is generally realized.

Imhoff Tanks

1. Sedimentation Compartment:

(a) Grease and scum in the sedimentation compartment should be removed daily. This is best accomplished where no mechanical means is provided, by the use of a dish-shaped perforated skimmer. Such grease and scum should be promptly disposed of by burying or burning. Where objectionable conditions are not likely to develop, the grease and scum may be placed in the gas vents.

(b) The sides and slopes of the sedimentation compartment should be carefully scraped with a rubber squeegee and all solids pushed down through the slots at least twice a week.

(c) The slot in the bottom of the sedimentation compartment must be kept open and free from obstruction of any kind. At least once a week the slot should be cleaned by the use of a heavy chain drag, taking care to traverse the entire length of the slot.

(d) Failure to carefully follow the foregoing operating procedure will usually result in an effluent of inferior quality and where a trickling filter is used there will be deposits and accumulation of solid material on or in such filter, due to grease, scum or sludge being carried through the tank.

(e) Where the design of the tank will permit, the direction of flow through the sedimentation compartment should be reversed at least once a month, in order to distribute the solids uniformly in the digestion or sludge compartment.

2. Gas Vents or Scum Compartment:

The scum in the gas vent should be broken up at least weekly to afford an easy escape for the gas from the digestion or sludge compartment. Control of the scum may be accomplished by some of the following treatments:

(a) Breaking the scum up with a hoe, rake, or other suitable tool.

(b) Hosing the scum in the gas vents with water under pressure.

(c) Punching holes through the scum at two-foot intervals with a wooden pole.

(d) The scum may be removed and dried in a sludge drying bed if its depth approaches 2 to 3 feet in the vents. Usually it burns readily and if incinerated may create a hazardous flash, due to grease content.

(e) Treatment of the scum in the gas vents daily with hydrated lime at a rate of about 10 lbs. per 1,000 population has been found to be helpful in controlling excessive scum formation and to aid in maintaining the pH value of the digesting sludge.

3. Sludge Compartment:

(a) The height of the sludge in the sludge compartment should be determined at inlet and outlet ends of the tank at least once a month. The use of a pump for this purpose is the most desirable and satisfactory. The use of the plate or disc method is not usually satisfactory. The following are suitable methods for measuring the depth of sludge:

(1) One method involves the use of a pitcher pump provided with a rubber suction hose, weighted on the end and the length marked on the hose at intervals of 2 feet, measuring from the weighted end toward the pump. The hose is gradually lowered through the slot in the sedimentation compartment, meanwhile constantly pumping, and the length of immersed hose, when sludge first comes through the pump is determined. When the sludge elevation is reached, the pump will usually "choke" before sludge appears.

(2) The sludge depth may also be determined by use of an iron plate or weighted wooden block, about 12-18 inches square, attached to a wire or chain lowered through the gas vent. The plate or block will stop when the sludge is reached and the distance from the surface to the sludge level is determined from the graduated wire or chain by which the device is lowered. The pump method is by far the most positive procedure.

(b) Sludge should be removed:

(1) Whenever the sludge depth approaches within 18 inches of the slot in the sedimentation compartment.

(2) In small amounts at frequent intervals rather than in large amounts at longer intervals. Usually some sludge should be drawn every month.

(c) Sludge should be removed at a slow regular rate to avoid the formation of a channel through the sludge in the sludge compartment and the withdrawing of partially digested sludge or the liquid above the sludge.

(d) If sludge does not flow readily, it may be started by:

(1) Agitating with water under pressure through perforated water pipes in the bottom of the sludge compartment, if such pipes are available.

(2) Applying water pressure through hose immersed into the sludge compartment or through the sludge riser pipe.

(3) Agitating around sludge inlet with long rods through the sludge riser pipe.

(e) Avoid withdrawal of all the sludge from the tank. Leave sufficient digesting or "seed" sludge to prevent the difficulties incidental to starting a new or completely cleaned tank. Usually not over half the depth of sludge in the tank should be removed at any one time.

(f) After use the sludge pipes should be flushed out and refilled with water or sewage to prevent the sludge from hardening and clogging the sludge pipes.

4. "Foaming:"

There are a number of possible causes for "foaming" such as industrial wastes like milk or cannery wastes, "mash" or "wine" wastes, drawing out too much sludge at one time, or increased temperatures in the sludge compartment. Foaming is almost invariably associated with an "acid" condition of the sludge and in such cases may be minimized or corrected by treatment to counteract the acidity. However, there is such a thing as alkaline foaming but it is not common.

When foaming occurs, there are a few simple treatments which may under certain conditions remedy or improve the condition.

(a) Relief may sometimes be obtained by drawing some sludge.

(b) Hosing the gas vent area with water under pressure will sometimes help.

(c) Cutting the tank out of service if possible and allowing it to rest will permanently improve conditions.

(d) Paddling the foam with long-handled hoes is also temporarily effective.

(e) Hydrated lime added through the gas vents at daily intervals will frequently correct a foaming condition.

(f) Treatment of the raw sewage with chlorine at rates of 20 to 50 pounds per million gallons will often bring foaming under control.

Trickling or Sprinkling Filters

1. The nozzles should be inspected daily. All clogged nozzles should be cleaned and any broken nozzles replaced.
2. The surface of the filter bed should be kept free from plant growths.
3. The formation of ponds or "pooling" on the surface of the

filter bed may be remedied or prevented by:
(a) Flushing the surface of the filter with a fire hose.
(b) Raking or forking the surface of the filter bed.
(c) Punching holes through the top layer of the filter medium with iron bars.
(d) Heavy applications of chlorine, chlorinated lime or other chemicals for short periods applied directly to the bed surface or in the filter bed influent at the dosing tanks. The treatment is usually most effective and economical if applied to the low night flows of weak sewage.
(e) Operation of units may sometimes be improved by cutting them out of service occasionally for a period of 12-48 hours.

4. Where the design of the filter bed will permit, the presence of large numbers of filter flies may be controlled by periodic flooding of the filter beds. Chlorine application, as for ponding, is also very helpful but not a 100% effective remedy. In flooding the sewage it should be chlorinated to delay oxygen depletion and septic action during the holding period.
5. The distribution piping should be flushed periodically.
6. The underdrains should be flushed out occasionally with water hose or other suitable flushing devices, if the filters are so constructed as to make this possible.
7. Where revolving distributors are installed, frequent inspection of water or mercury seals should be made.
8. Where revolving distributors are installed, the flow from the nozzles should be adjusted so that the flow delivered is proportional to the area covered, i. e., the end nozzle should deliver twice as much as the one half-way out from the center. The center nozzles should deliver very little flow—only thin share for the ratio of area covered.

Secondary or Final Settling Tanks

1. The sludge should be removed frequently to prevent septic action and gasification of the solids which results in discharge of solids with the final effluent. This cleaning is usually necessary at least once a month, or oftener, during the summer season.
2. The depth of the sludge should be determined at frequent intervals by the use of a sludge sounder or other device.
3. The sludge may be disposed of in the same manner as sludge from primary settling tanks, i. e., pumped into primary settling tanks or into separate sludge digestion tanks direct for digestion. In the latter case density of the sludge is an important consideration to perclude the effects of dilution on the digesters.

Sludge Drying Beds

1. Sludge beds should not be filled to a depth of more than 12 inches or to such a depth that the sludge cake cannot be removed within two weeks in good drying weather.
2. The surface of the drying bed should be kept clean and free from all previously discharged sludge. *Never discharge wet sludge upon dried or partially dried sludge.*
3. The surface of the sludge drying beds should be kept nearly level to afford an even distribution of sludge over the surface of the bed.
4. Dried sludge may be used for fill, buried, or spread upon the ground, where it will not be carried into a stream or watercourse by rain.
5. In many communities the sludge is readily disposed of by giving or selling it to nearby farmers for use as fertilizer. This should be encouraged as sewage sludge has been found to have fertility and soil improving values. It is not advisable, however, to use it for the fertilization of crops which are served in an uncooked condition. For best results the sludge cake should be shredded or pulverized before attempting its sale.

Sand Filters

1. The beds should not be used continuously but sufficient time should be allowed between doses for the bed to drain thoroughly and "rest" between applications. Satisfactory operation of a filter bed depends on the presence of oxygen in the bed and therefore opportunity for the entrance of air into the bed must be provided by the "rest" periods.
2. The beds should be periodically cut out of service, allowed to dry and the surface raked or scraped clean.
3. "Pooling" should not be allowed to develop on the beds as this tends to produce septic action, obnoxious odors and an effluent of poor quality. Pooling indicates that cleaning is necessary. Frequently a harrowing is all that is required. Eventually skimming will be required.
4. The surface of the beds should be kept level to afford uniform distribution of the sewage.
5. Weeds, grass, etc., should not be allowed to grow on the beds.
6. The depth of the bed should be maintained by removing during cleaning only the least possible amount of sand. Once a year clean sand should be added to replace that removed during the year.
7. Where natural sand percolation beds are used it is sometimes advisable to shallow harrow the beds after careful removal of all organic deposits.

Chlorination

The purpose of chlorination is to prevent bacterial contamination of streams or other bodies of water, used for municipal or industrial water supplies, irrigation, shell-fish growing, recreation or bathing.

The effective chlorination of sewage or sewage effluents depends upon the presence of adequate quantities of chlorine at all times in all portions of the sewage for sufficient time to provide the necessary period of contact between the disinfectant and the bacteria in order that disinfection may be efficient.

The strength of any sewage varies greatly with seasonal changes, with the days of the week and during the hours of the day. The amount of chlorine required varies accordingly.

1. Chlorine should be applied in such quantity that there will be a residual of at least 0.5 p.p.m., as determined by the ortho tolidine test, after 15 minutes contact of chlorine with the sewage or the effluent, depending upon whether pre- or post-chlorination is practiced.
2. The test for residual chlorine should always be made at the time when the sewage or effluent is the strongest or when it requires the largest amount of chlorine for treatment.
3. Weigh chlorine tank each day at the same time to determine the amount of chlorine used during the preceding 24-hour period.
4. The chlorine must be applied *continuously* in the proper quantities.
5. Before connecting a new chlorine cylinder to the control apparatus, blow off some of the chlorine from the new cylinder into the air in order to prevent clogging of the apparatus. Store the empty cylinders apart from the full ones so as to avoid mistaking empty cylinders for full ones.
6. Examine the chlorine apparatus daily and if any trouble is found which cannot be corrected by the operator, notify your superior at once.
7. It is not advisable to draw chlorine from any one cylinder at rates higher than 40 lbs. of chlorine in a 24-hour period, because of the danger of "freezing" and slowing up the chlorine flow. If more chlorine is necessary, two or more containers should be connected and used in parallel.
8. The operator should always have on hand a stock of the usual replaceable parts for the chlorine apparatus and a reserve supply of chlorine cylinders.
9. Leaks in the chlorine apparatus should be promptly repaired to prevent corrosion of the equipment and structures. Such leaks may be detected by the formation of white fumes when tested in the immediate vicinity with the vapors from an ammonia solution. (Household ammonia is satisfactory).
10. During cold weather heating facilities should be provided to maintain a temperature of 60° F. and never less than 50° F. in order to prevent so-called "freezing" in the chlorinator and stoppage of the chlorine flow. It is frequently necesssary to heat the water supply to the tray of the chlorinator to prevent "chlorine-ice" formation.
11. Chlorine is a liquid when under pressure in the cylinders and is an irritating gas which is heavier than air when released. It may produce serious after effects if inhaled. A satisfactory gas mask should be available at all plants where chlorine is handled.

Activated Sludge Tanks

1. Sludge percentage tests (settling for ½ hour a liter graduate) should be run twice daily on the mixed liquor of the aeration tanks, sampled at the half-way point.
2. When the sludge percentage of the mixed liquor exceeds 30% (300 c.c. in the liter graduate), sludge should be withdrawn. Some plants have been found by experience to operate more efficiently at a lower per cent.
3. Excess sludge should be wasted into the raw sewage if primary sedimentation is practiced or wasted directly to digesters or via thickener tanks if these are provided. Such tanks are an important adjunct to the functioning of digesters.
4. Direct drying of untreated sludge results in odor and fly nuisance.
5. For small plants, dissolved oxygen tests on the effluent

from samples taken from the clarifiers should be run daily. B. O. D. and suspended solids tests on the effluent should be run at least twice weekly.

6. Cracked or leaking air diffusion plates should be watched for and quickly repaired.
7. Air and sewage regulating valves should be operated at least once a month to insure against sticking.
8. Bulking is said to occur when unusual amounts of suspended solids pass out with the effluent. It may sometimes be controlled by one of the following practices:
   (a) Increasing the supplied air or reducing the solids carried in the aeration units.
   (b) Continuously adding lime sufficient to bring the pH up to 9.0 (for small plants).
   (c) Adding small amounts of fine clay (for small plants).
   (d) Moderate chlorination of the returned sludge.
   (e) Bypassing the sewage until condition is corrected.
   (f) Eliminating industrial wastes from the sewerage system when these are proven to be causative.

If bulking becomes a chronic problem, the administrative authority should be fully informed and an investigation by a competent sanitary engineer recommended.

9. Air pressure on this diffuser manifold should be recorded regularly, as increase in pressure results in increased power cost.
10. Operation of final settling tanks is similar to operation of primary settling tanks.

Neatness, Cleanliness, Beautification

1. It is very easy for a sewage plant operator to become negligent. The appearance of his plant reflects in most cases his own character.

2. A limited planting of shrubs and trees will add greatly to the appearance of a plant. Most administrative authorities, if properly approached, will provide at least in a small way, for this improvement. Select hardy plants which require a minimum of attention.

3. Paint is an investment. A plant where painting is neglected will soon require expensive replacements. Learn all you can about paint; many conditions require special paint.

4. A set of neat, well-kept records is a convincing argument when an operator is asking for improvements.

5. A clean plant is usually a well-run plant.

6. An untidy plant is a hazard to life and limb. Slippery steps, unused equipment left in the way, can be the cause of a nasty fall.

7. Work around sewage is always subject to health hazard; extra care and cleanliness are, therefore, essential. A first-aid kit should be on hand and used for even minor injuries. Arrange for prompt medical service for more serious accidents.

8. Make a study of the life cycle of flies and mosquitoes. A knowledge of this subject will enable an operator to control with a little thought and effort, most insect nuisances.

Last but Not Least

9. Join and take an active part in your local sewage works association. The journals and the exchange of operating experience with other members is a rich source of progressive ideas.

Acknowledgement—This paper constituted a lecture in the Water and Sewage Tanks Operators Short Course of the 11th Annual Institute of Government at the University of Southern California, Los Angeles

SOLUTION FEED CONTROL

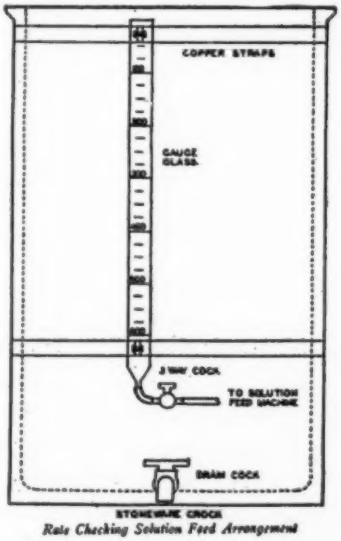
By T. M. RIDDICK

Consulting Chemist, New York City

WITHIN the past few years there has been a rapid increase in the use of solution feed equipment for pressure filters, and small water supplies with pumping rates of less than about 700 GPM. This trend now fills the long-felt need for apparatus of a capacity below that of standard dry feed machines or vacuum-type chlorinators. These feeders are of diaphragm or piston type and discharge roughly a maximum of 250 ml. per minute for single units, with duplex rating of approximately twice this figure. Experience with both plunger and diaphragm pumps, operating under a negative head, emphasizes the possibility of flow stoppage due to clogging of suction or discharge lines, loss of prime through air leakage, air binding, etc. If the machine is fed by a suction hose extending over the rim of the solution crock it is most inconvenient and difficult to judge at what rate the solution is being added, and whether the discharge is constant.

A new type of solution feed arrangement is shown in the accompanying drawing. It has been used with excellent success by the writer.

The crock illustrated is a fifty-five gallon stoneware pot of substantial construction. The draincock can be furnished as standard equipment and provides an easy way of drawing off sludge which will in time accumulate from commercial chemicals. Six inches above the center line of the draincock is placed a three-eighth inch three-way hard rubber cock and T. (See sketch.) This location prevents clogging of the feed line by sludge or chemicals which have not completely dissolved. (It is better to have this cock installed at the factory, since the hole may be drilled more readily at the shop than in the field.)



Rate Checking Solution Feed Arrangement

The gauge glass is made by drawing down one end of heavy-walled Pyrex tubing of 38 mm. diameter. The tube, as pictured, is calibrated at 25 ml. and number marked at 100 ml. intervals. However, it may be graduated at intervals of 10 ml. with no overcrowding of division lines. The gauge glass enables the operator to observe the height of solution in the crock without close inspection, and also affords a means for measuring the amount of solution used daily since the tube calibration may be interpreted in terms of gallons of crock capacity, or pounds of chlorine, alum, ferric-chloride, etc.

In order to ascertain the specific rate of feed, it is only necessary to turn the threeway cock 180 degrees. This causes the solution to be drawn from the gauge glass instead of from the crock, and by noting the time (in seconds) required for a drawdown of say 100 ml., or, by observing the drawndown in ml. for a period of one minute, the rate of discharge of the feed machine can be accurately established.

It also serves as a very ready method for determining whether or not the machine is feeding at all. For instance, clogging of the feed line often occurs when using chemicals shipped in burlap bags, due to small threads which pass into the crock when bags are emptied.

The gauge glass is held in place by two copper or monel straps, which secure it to the solution pot.

It is advisable to attach a high speed mixer to the crock to assist the operator to quickly and easily prepare solutions. When hypochlorites or ferric salts are used the shaft and propeller of the mixer should be coated with rubber or heavy bituminous enamel.

The cost of the equipment is negligible when considering the operating facilities afforded.

*From WATER WORKS AND SEWERAGE.

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Ammonia Control Apparatus Dry Chemical Feed Devices, etc.

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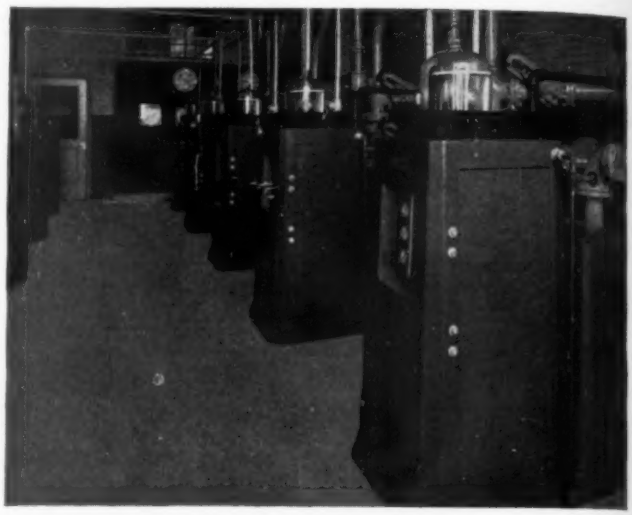
CHLORINATION OF SEWAGE

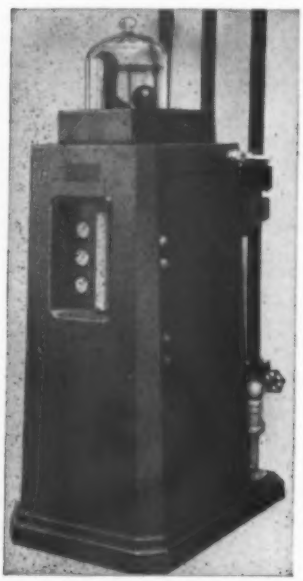
Of all chemicals used in sewage treatment, chlorine has by far the widest application. From simple disinfection to use as an adjunct to the most involved treatment process, chlorination has for years been the versatile and valued aid of the man concerned with sewage disposal.

Regardless of the preliminary process of sewage treatment, disinfection of the effluent before discharge is regarded as a necessity. Protection of water supplies, bathing places and shellfish propagation beds, requires efficient disinfection by means of chlorination.

Chlorination is employed to stabilize raw sewage, control odors, increase efficiency of filter beds, prevent filter ponding, improve sedimentation, remove settleable solids, improve sludge digestion, prevent bulking, reduce biochemical oxygen demand, retard putrefaction in the receiving water course, and is a necessary adjunct to nearly any process of chemical precipitation.



Five W&T Master Visible Vacuum Chlorinators operating at Bird Island Sewage Plant, Buffalo, N. Y.



Master Visible Vacuum Chlorinator — W&T Visible Vacuum Control is now available in equipments ranging in capacity from .03 to 6000 pounds of chlorine per 24 hours.

ODOR CONTROL

Control of odors from sewage treatment works, long outfall sewers and other disposal plant appurtenances is a field for chlorination. Neutralization of hydrogen sulphide (the gas responsible for these obnoxious odors) or prevention of its formation by controlled application of chlorine, is not only practical but also results in economy of operation.

B. O. D. REDUCTION

In order to prevent production of odor nuisance, foul appearance and death to fish life in streams receiving the effluents from sewage disposal plants, chlorination for B. O. D. reduction has become increasingly popular. Offering a simple, easily controlled and relatively inexpensive means of supplementing other purification processes during periods of low stream flow or for permanent use at a plant where the dilution factor is low, chlorination has eliminated the necessity for extensive additions to the regular treatment works.

IRON SALTS IN SEWAGE TREATMENT

Lowered cost of chemicals and other contributing factors have greatly increased the popularity of iron salts for various uses in sewage treatment, odor control, sludge conditioning, chemical precipitation, etc.

In whatever form this treatment may be adopted, such as the manufacture of ferric chloride at plant site, the addition of ferric chloride or of ferric sulphate directly, or the use of chlorinated copperas, W&T are prepared to furnish the necessary equipment. Complete details on request.

CHLORINE FLOW RECORDERS

Chlorination records form an important log of plant operation and are indisputable evidence that proper application of chlorine was made. Periodic visual inspection will not reveal when equipment may have been temporarily out of service for cylinder change-over, cleaning or any other cause.

The W&T Chlorine Flow Recorders meet the need for continuous automatic flow recording. These are of two types: the "Direct air transmission type" for continuous recording of chlorine flows, and the electrically operated type which provides indicating, recording and totalizing. The electric type is particularly suitable for use with a battery of chlorinators.

CONTROL OF ODOROUS AND DESTRUCTIVE GASES IN SEWERS AND TREATMENT PLANTS

By CHAS. C. HOMMON
Supervisor of Sewage Treatment
Canton, Ohio

THERE are heterogeneous odors from sewers and sewage treatment plants. The so-called sewer gas often referred to in nontechnical language by the layman is not a specific gas. It is an all inclusive term meaning any gas or combination of gases that may be found in a sewer. The most objectionable and far-traveling odorous gases are those originating from stale and septic sewage. Of these volatile compounds, which are expelled from septic sewages, hydrogen sulphide is by far the greatest offender.

This gas, besides creating odor nuisance of intensity and travel distance in proportion to its concentration, has a second and decided objection. It is a dangerously toxic gas in dilution higher than most operators and engineers realize. By authorities it is rated with hydrocyanic acid gas in respect to its toxicity. It is treacherous because individuals working in fatal concentrations lose their sense of smell. Operators working in less than fatal concentration become accustomed to the odor but in time suffer permanent injuries—notably conjunctivitis and respiratory tract inflammation.

Destructive Effects of Sulphide Gas

In addition to the toxicity, hydrogen sulphide is responsible for costly damages to sewers and plant equipment. Copper parts on expensive switchboards and control panels are in short order sulphided and flaked away or crumble to black copper sulphide powder. Short work is made of copper screens and brass work exposed to the moist gas at sewage plants. The first sign is the iridescent blue coloring imparted to copper and its alloys. Hydrogen sulphide can also be easily and simply detected by exposing silver coins for a few hours at points where presence of the sulphide gas may be suspected. The coins turn brown and then black if sulphide gas is present.

Then, one of the most disastrously damaging effects from hydrogen sulphide is its hidden attack. This is the acid disintegration of masonry sewers and all metal parts of manhole structures. The sulphide gas in this type of attack is converted by organisms (bacteria) on the walls of sewers into two acids, sulphurous and sulphuric. It hardly needs be explained that both of these acids make short work of concrete or mortar. The calcium sulphate produced causes rupture of mortar pipe joints and brick sewers or manholes. It has been known to weaken sewers to the point of complete failure of that part above the sewage flow line, below which no damage is done. Therefore, no full flowing sewer is ever damaged by sulphide gas. This gas is never oxidized by organisms which are present in the liquid but only those which thrive in an atmosphere where there exists some oxygen. If, therefore, it were practical to seal sewers so as to prevent all entry of air, there would be no danger of the so-called gas attack of sewers and manholes.

An Instance

The sanitary outfall sewer extending from the southerly city limits of Canton, Ohio, to the treatment plant offers good evidence as to the destructiveness of sulphide gas.

This sewer is 39 inches in diameter, 6.5 miles in length, and was placed in service in 1915. Type of construction was vitrified segment block laid up with mortar joints, and has a theoretical carrying capacity of 18 m.g.d. There is one depressed section, 3,200 feet in length, which is constructed of reinforced concrete. This length of sewer is naturally conducive to septic sewage and consequent development of hydrogen-sulphide, especially during the warmer months of the year. The presence of offensive gases was not particularly grievous with the Imhoff contact bed type of sewage plant that was the original companion unit of this outfall sewer. However, in 1925, when the original contact bed units were converted into trickling filters using the conventional spray nozzles that were in general use at the time, the volatile gases made their presence known through the atomizing effect of the spray nozzles. Thus originated a definite odor problem.

An Early Study in Corrective Treatment

In about 1928 through the efforts and assistance of Mr. L. H. Enslow, associated with The Chlorine Institute, some work was undertaken using liquid to control the odors. The Institute furnished the chlorine and the firm of Wallace and Tiernan loaned the necessary chlorine feeding apparatus for the study.

Chlorine was first added to the sewage at a point locally known as the three way manhole, which is the beginning of the main outfall sewer. This station is 6.5 miles above the Treatment Plant and is the point of convergence of three main trunk sewers.

A number of sampling points were established along the sewer for collecting samples for analysis. It was soon learned that the chlorine would do the trick of controlling the hydrogen-sulphide. However, it was difficult to maintain sufficient chlorine and the required dosage was relatively high. The receding area in the depressed section caused an appreciable increase of hydrogen sulphide which, it was believed, defeated the desired results at the plant. It was obvious that split feeding was the answer; just how many points of desired application were not determined because of the absence of necessary water pressure for operating the chlorine machines at locations below the three-way manhole.

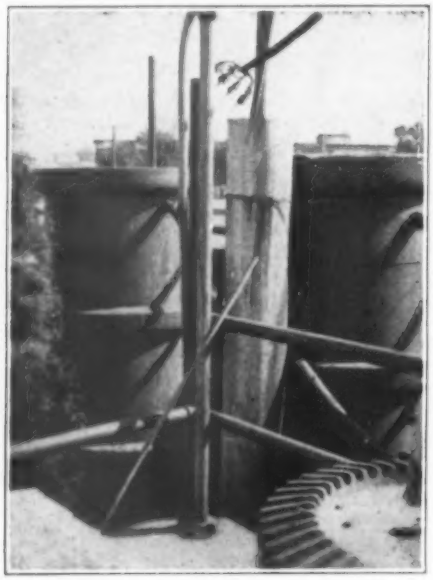
The chlorinators were then moved to the sewage plant and chlorine admitted to the raw sewage just ahead of the bar screens.

This work clearly indicated that a dosage of 10 to 12 p.p.m. would greatly improve conditions at the plant and eventually permanent chlorination equipment was purchased and storage

One of the Early Up-Sewer Chlorinating Stations for Odor Control and Sewer Protection—San Bernardino, Calif. This picture reveals the small space required for such a station and the method of transfer of the one-ton chlorine cylinder from truck to the in-use pit alongside the chlorinator house. Incidentally this picture was taken just after California's worst floods and half-buried the chlorinator house in deposited silt. With the treatment plant put completely out of commission, this station performed an emergency service of disinfection of the bypassed sewage during the restoration by merely boosting the chlorine dosage.

racks for handling ton containers of chlorine was constructed. At this time odor control was the all absorbing question, with only minor consideration given to the need for deterring disintegration of the mortar tile joints and concrete structures.

Attack on these, however, became accelerated in the time intervening and the expensive Canton outfall sewer, weakened by joint attack, has ruptured three times in the past few years. Internal pressures, caused from surcharging, proved too much for the weakened joints. These failures offered good reasons and opportunities for a thorough inspection of the sewer and it was found that practically all of the mortar joints above the normal flow line had disintegrated and ceased to exist. Also many of the liner plates were split off and were found lying on the floor of the sewer. It is assumed that the swelling of the mortar in the joints during the sulphating period created sufficient pressure to pinch off the faces of these tile. In a few instances the velocity of the sewage had caused these fallen plates to gather into sufficient piles to develop major restrictions in the sewer. It was interesting to note that the portion of the sewer below the normal flow line was in a very satisfactory condition, no plates missing and all joints normal, whereas the upper areas showed serious attacks. This same condition prevailed in the approaches to the concrete depressed section. Wherever the concrete mortar was submerged it was in a satisfactory condition, but above the normal flow line (those areas normally in contact with moisture and the gases) serious deterioration was evident.



The Original Contact Towers for the Scott-Darcey Process of Making Ferrous and Ferric Chloride at Oklahoma City.

Discharge from chlorinators passes upwards through iron scrap, producing ferrous chloride.

A great deal more is known today about sewage treatment and the handling of sewage than was available when the Canton outfall sewer was constructed and the writer is frank in admitting that he did not fully appreciate what had occurred or what was occurring in the sewer at the time this investigational work was being done. As a matter of fact, there was little if any evidence in 1928 to show that the attack was proceeding at a serious pace, and chlorination at the plant proper seemed adequate for the odor problem.

Methods of Preventing Sulphide Production

Hydrogen sulphide develops only after all other sources of available oxygen utilizable by bacteria have been exhausted. After this, the oxygen hunger of several species of bacteria is satisfied from the only source left—the sulphates. In taking away the oxygen, the residue is sulphide, which hydrolizes into hydrogen sulphide.

Having laid down this premise, it becomes apparent that there are two general methods of preventing or checking sulphate breakdown. These are:

(1) Introducing more oxygen in the form of air, dilution water containing oxygen, or an oxygen containing compound such as nitrate.

(2) Suppression of bacterial activity and multiplication of organisms which deplete the oxygen and eventually break down the sulphates for their oxygen content.

The sewage operator may employ the following corrective methods:

(1) Air blowing to sweep out most of the volatile (free) hydrogen sulphide and discharge of the air-sulphide exhaust through a tall stack. Or absorption of the sulphide in the exhaust may be attained by passing it through an absorption tower.

(2) Destruction of the sulphide in the sewage by addition of chlorine, which precipitates the sulphur *in situ* and deodorizes in so doing.

(3) The fixation of the sulphide by adding a metallic salt such as copper or iron.

These several methods will now be discussed separately.

(1) Oxygen Introduction

Air blowing in the sewer sounds attractive but has many drawbacks of a practical nature. The scheme has never been successfully developed because of structural and operating expense. The effect secured with flash aeration has short duration, as all activated-sludge plant operators will attest. As a matter of fact, a small air input is worse than none in the overall result, since bacterial multiplication is given impetus and oxygen supply is too limited.

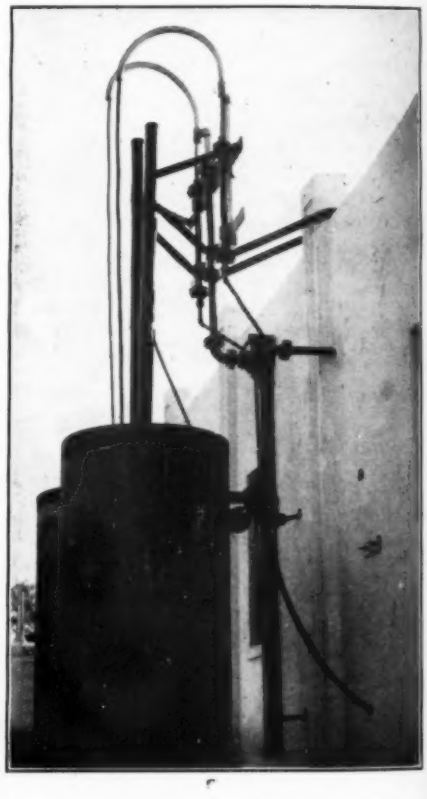
The addition of nitrates (Chilean Saltpeter) has been used; is effective but surprisingly costly in terms of oxygen units provided.

Dilution, by introducing reasonably clean stream water upsewer, has been utilized with excellent results during hot dry-weather flow when the practice is most needed, and fortunately is permissible at such times without surcharging sewers or imposing excessive flows on treatment works. Fortunate is the plant manager who can divert a portion of a stream into his sewer system when most needed to maintain clean sewers, dilute and freshen sewage delivered to the plant at much younger age, and prevent degradation and odor production in the system.

(2) Suppression of Bacterial Activity

In winter, lower temperatures of sewage is the natural suppressor of bio-activity. If it were practical to chill sewage to maintain temperatures of not in excess of 70° F. during its travel through the system there would be no odor or sewer attack problem.

The practical alternative is that of partial disinfection of sewage to reduce the total numbers of organisms, suppress their development, and most important of all, to reduce the biological "turnover." What is meant by "turnover" is the number of new generations of young and vigorous organisms per hour. Like all living things, it is the active youth generation who burn up the oxygen in the vigor of living, and not the grandfather generation. Total numbers of organisms may mean little if anything in sewage. What really counts is the age, activity and species of bacteria. This means much in rate of oxygen utilization and depletion, consequently, the speed of reaching the point of sulphide production and its consequences.



Contact Towers for the Scott-Darcey Process at a Small Treatment Plant in Arizona.

In this instance the chlorinated iron produced is employed for chemical precipitation as well as odor control.

To suppress bacterial "turnover" and rates of oxygen deple-

tion, such as is provided by nature in winter operation, is the basis on which partial disinfection of sewage as close to its point of origin as practical, has met with success. Some remarkable results have thus been obtained with up-sewer chlorination at rates of dosage dictated by the temperature-time factor. In some instances (cooler sewage and short period of travel to the plant) as little as 2 p.p.m. of chlorine has been ample. In other instances (drought and high temperatures with long travel periods to the plant) as much as 12 p.p.m. has been required. In others, a two-point application, between the collecting system and the plant, has been required for higher efficiency and chlorine economy. Taking it by and large, the 5 p.p.m. dosage has been effective when applied sufficiently early—i.e., before bacterial "turnover" has gotten a head-start.

During the past several years "preventative chlorination" has been the most popular odor control measure. No set rule can be given for the dosage needed, for reasons above cited. Nor can a universal specification be written concerning the point (or points) of chlorine introduction up-sewer. Therefore, in cases where doubt exists, a hydrogen sulphide and chlorine-demand survey to determine the most effective application point (or points) is the recommended procedure. As a matter of fact, a portable chlorinator may be employed to determine the permanent location (or locations) for maximum chlorine economy.

In connection with such surveys and chlorination point selection, securing assistance of experienced engineers with The Chlorine Institute, 50 E. 41st St., New York City, or the technical service staff of Wallace & Tiernan Co., and/or of the larger chlorine producers, is suggested.

Other Corrective Methods

In cases where it has not proved practicable to adopt preventative measures, the following corrective methods are available.

(1) Air Blowing at Plant

So far as we are aware, this method has only been utilized at one plant—Dallas, Texas. In a closed chamber the sewage arriving at the treatment works is air-blown for 4 minutes and in the second pass is blown for an additional 4 minutes with air carrying chlorine gas. The exhaust from the aerating and aero-chlorination chamber is discharged through a stack. The plant is also equipped to employ ordinary chlorination or the addition of an iron salt, which will destroy or "fix" the volatile sulphides, as later explained.

(2) Chlorination

By far the greatest number of plants have been equipped for corrective chlorination at the plant proper, when and if odors become a problem. Particularly has this method been mostly adopted for the smaller plants and those where odor nuisance is a possibility rathter than a probability.

In this method, chlorine is applied just ahead of the bar-screens or in the pump well. The dosage varies considerably, running from 2 to 20 p.p.m. of chlorine. In the majority of such cases, the 10 p.p.m. dosage covers the requirement. The practice of pre-chlorination for the dual purpose of disinfection and odor control simultaneously has gained considerable favor in recent times, the largest plants to adopt this method being those of Buffalo, N. Y., and Detroit, Mich., where pre-chlorination has also proved more economical than post-chlorination, and also more effective as a disinfection measure alone.

In the plant chlorination method the sulphide is destroyed by breaking into the compound and precipitating the sulphur thus

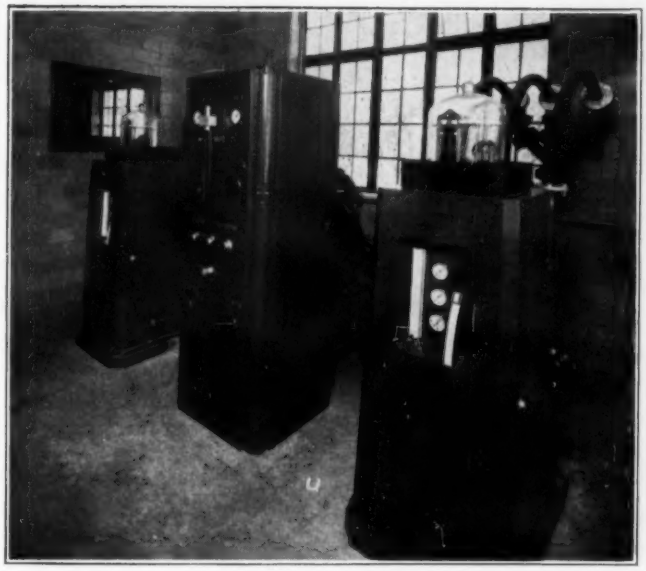
$$H_2S + Cl_2 = 2HCl + S$$

(3) Sulphide Fixation

When adding chlorine *solely* for the purpose of sulphide destruction (i.e., after the sulphide has been produced), the scheme is less effective than the following.

Copper or iron salts may be employed for the purpose of converting volatile sulphide into "fixed" copper or iron sulphide. Since copper is the more costly metal, and since iron chloride can be produced relatively simply and inexpensively on the site of application, this scheme has in recent times become a very popular, effective and inexpensive method.

The iron chloride is produced from scrap iron and chlorine by passing the discharge of a chlorinator upwards through a tank or tower containing the iron scrap. The overflow from the tower is ferrous chloride ($FeCl_2$). The process introduced in Oklahoma City by L. H. Scott, Supt. of Water and Sewage Treatment, and H. J. Darcey, Chief Engr., Oklahoma State Dept. of Health, and known as the Scott-Darcey Process, was taken over and perfected by Wallace & Tiernan Co. In the West and Southwest the method has been rather extensively and effectively used. With the equipment, either iron chlorine or chlorine may be used at will. The equipment can also be operated to produce ferric chloride ($FeCl_3$) for coagulation or sludge filtration at will.



The Triple Purpose Chlorinator Installation at Dallas, Texas The 1,000-lb. capacity dry feed machine at center is used for "Aero-Chlorination" in grease separation and/or deodorization of stack gas. The two 2,000-lb. capacity solution machines are used for prechlorination odor control or producing chlorinated copperas at will.

In the matter of odor correction, the use of chlorinated iron has many advantages over direct chlorination. For instance, there are stale sewages which when chlorinated partially develop decidedly medicated (iodoformish) odors. This odor is not of a traveling nature but is not pleasant and visitors would object to it. On the other hand, chlorinated iron produces absolutely no odor. For a given amount of chlorine, use of the Scott-Darcey method insures 100 per cent efficiency in respect to theoretical hydrogen sulphide removal per pound of chlorine. The explanation lies in the fact that the iron has affinity only for the sulphide and fixes it completely without organic matter interference, while chlorine is always in part used up by organic matter before it strikes the sulphide. Frequently 50% of the chlorine applied is thus used up and only 50% ever reaches the sulphide.

A fact of considerable interest also is that the iron application can be made at any point desired. If, for instance, it is desirable to add it at the beginning of a long sewer, the iron is used up only as hydrogen sulphide is produced. Therefore, the surplus of iron travels along in contact with the sewage or industrial waste without being depreciated in any degree by the organic content. Thus, the iron becomes available as needed during progress of the sewage between the point of application and the plant. It is plain, therefore, that the chlorinated iron method is a measure of correction which involves the utilization of chlorine to its highest advantage. The method insures an efficiency of hydrogen sulphide removal at essentially 100 per cent of the theoretical, this being the destruction of 1 p.p.m. of H_2S for each 2 p.p.m. of chlorine applied, according to the reaction:

$$H_2S + Cl_2 = 2HCl + S$$

The reactions involved in the chlorinated iron method are:

(1) $Fe + Cl_2 = FeCl_2$

(2) $H_2S + FeCl_2 = 2HCl + FeS$

Since two parts of chlorine by weight accounts for one sulphur, the iron involved can be pictured as a chlorine carrier in the process of "indirect chlorination."

From the above, it is readily observed that the more modern use of chlorine as an agent of controlling hydrogen sulphide would have been of material benefit in preventing failure of Canton's 26 year old outfall sewer, as well as correcting the odor problem at the plant proper. When considering the cost of a large outfall of material length it is apparent that considerable can be spent for Summer time chlorination as a measure for extending the life of such a structure.

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DEGREASING SEWAGE

Experiences With the Aero-Chlorination Method

By GORDON J. WIEST

Chemist, Sewage Treatment Works, Lancaster, Pa.

The separation of grease and oils from raw sewage is recognized as important to most sewage works operators, because the presence of these buoyancy producing materials in sewage lowers primary sedimentation efficiencies. Furthermore, they apparently interfere with efficient aeration and final clarification in the activated sludge process.

The method for degreasing sewage has been to aerate the sewage, utilizing air diffusion, for a short period as it flows through a channel or tank ahead of sedimentation tanks. This method has been practiced in a number of activated sludge type plants. The theory is that a violent diffusion of air bubbles sweeps the particles of grease and oils to the surface where coalescence and floatation results. The removal of the grease follows the pre-aeration and is effected by tank skimming by hand or with the aid of mechanical devices.

History

H. A. Faber, of the Chlorine Institute, in 1937 reported an improvement of this method of grease separation as a result of an experimental study conducted under his direction on a full plant scale at the Woonsocket, R. I., Sewage Treatment Works. Faber's method* was to admit gaseous chlorine into the air line serving the grease separation tank. This method of employing chlorinated air for grease separation has now come to be known as degreasing by "Aero-Chlorination." Faber reported an average chlorine dosage of 1.5 p.p.m. (based on sewage flows), with an average detention period of six minutes, increased the grease removal from 189% to 442% as compared to the use of aeration alone and employing the same quantity of air and contact period. The percentage increase in grease removal was based on pounds of wet grease (scum) removed per million gallons of sewage treated. Keefer and Cromwell, at Baltimore, Maryland, conducted similar experiments on a semi-plant scale at the Back River Sewage Treatment Works which results* confirmed Faber's findings at Woonsocket.

Lancaster Conditions

An investigation of the grease and oils present in the sewage at the South Plant in Lancaster, Pennsylvania, led me to believe that our difficulties could be minimized by attempting a method to increase the efficiency of our grease separation facilities. A laboratory investigation showed that grease and oils were present in the raw sewage delivered to the South Plant in rather variable and also comparatively high quantities. This laboratory investigation included a study of the grease content of the activated ("return") sludge. The "return sludge" at the South Plant averaged 21.63% (dry basis) grease, while the "return sludge" at the North Plant averaged but 5.0% grease. Briefly, Lancaster, Pennsylvania, has two sewage treatment plants—both being conventional activated sludge type design with separate sludge digestion. The North Plant was placed in operation in December, 1934, and has produced a high quality effluent with a minimum of difficulties. The South Plant, placed in operation in May, 1935, has since that time continuously offered a variety of problems which interfere with good operation.

The Lancaster Plants were designed for pre-aeration ahead of the primary sedimentation tanks. Screenings and grit are removed ahead of the pre-aeration channels. The pre-aeration channels are 6.5 feet in depth with diffuser plates on the bottom of the channels. The air delivered to these channels is measured and recorded in the Main Building. The grease removal after pre-aeration is effected by means of mechanical skimmers which carry the grease across the surface of the primary sedimentation tanks to the effluent end, where cross-skimmers remove the grease to collection pits. The grease is removed from the collection pits to the digestion tanks as required. The operation of the skimmers is not continuous; they are placed in operation for an average of five non-consecutive hours daily. The average detention period in the primary sedimentation tanks is 1.75 hours.

A Form of Aero-Chlorination Tried

The use of a form of Aero-Chlorination with hopes of improving grease separation was started at the South Plant under plant scale conditions in August, 1937. Chlorine in a gaseous form could not be injected into the air line serving the pre-aeration channels. So, a W. & T. vacuum type solution feed chlorinator was set up to feed chlorine in solution directly to the raw sewage just ahead of air diffusion. The chlorine solution feed line was anchored in front of a baffle submerged directly ahead of the sewage delivery line. This insured thorough mixing. The dosing of the chlorine (as at Woonsocket and Baltimore[1-2]) has been calculated on the basis of raw sewage flow, for ease in interpretation and weighing of data—including costs of the procedure.

Point of Chlorine Application
(Pre-aeration channel, with chlorinator house on left. Note the violent aeration at this point, for rapid and most effective distribution of small dosages of chlorine.)

A number of preliminary tests were made alternating aeration alone with Aero-Chlorination—as we shall designate the procedure, even though not strictly Aero-Chlorination. Comparisons were made from the appearance of the grease collecting on the surface of the primary sedimentation tanks. Aero-Chlorination invariably produced more grease on the primary tanks than aeration alone. Variable dosages of chlorine were applied to the sewage mixed with air and it was found that chlorine was lost when applied in excess of 3.0 p.p.m. (This gives some indication of how closely the air blowing followed the chlorine application.) An average of only 2.0 p.p.m. has been applied throughout the experimental measurements, to avoid possible loss of chlorine, and also because preliminary results indicated that a dosage of 2.0 p.p.m. was effective for the treatment desired.

Analytical Procedure

The performance of Aero-Chlorination, under plant scale conditions, was measured during defined experimental periods by determining the grease content of the raw sewage ahead of pre-aeration and of the effluent from the primary sedimentation tanks. The percentage grease removal was computed from the analytical

results. The grease content of the raw sludge was also determined and the total grease removed computed. The method for the grease determinations followed Standard Methods of Water & Sewage Analysis (A.P.H.A.). The grease extractions were made, using petroleum ether throughout the experimental measurements reported. The grease was removed from the collection pits daily during experimental measurements and the weight was recorded after draining for not less than one hour. The weight of the grease was reported on a wet basis as pounds of wet grease removed per million gallons of sewage treated. The performance of Aero-Chlorination was compared with aeration alone, then without aeration or chlorination, and then chlorination alone. The grease content of the activated ("return") sludge was reported from time to time, since it is felt that the grease content of the "return sludge" may determine the efficiency of the activated sludge during aeration of the sewage sludge mixtures.

Results

Aero-Clorination Alone

Experimental measurements were made from August 14th to 24th, 1937, using Aero-Chlorination. The chlorine dosage was 2.0 p.p.m. The experimental measurements continued from August 26th to 31st, 1937, using aeration alone. The results are shown in Table I. On the basis of the weighed pounds of wet grease removed per million gallons of sewage treated, Aero-Chlorination increased the grease removal 308% (see table) over the treatment using aeration alone. Laboratory analytical results showed a grease removal of 76%, using Aero-Chlorination and a grease removal of 53%, using aeration alone.

These experimental measurements were repeated from September 5th to 15th, using Aero-Chlorination and comparative tests were made September 20th to 30th, using aeration alone. The chlorine dosage was 2.0 p.p.m. The results appear in Table II. On the basis of pounds of wet grease removed per million gallons of sewage treated, Aero-Chlorination increased the grease removal 373% over the treatment using aeration alone. Laboratory analytical results showed a grease removal of 78%, using Aero-Chlorination, and a grease removal of 63%, using aeration alone.

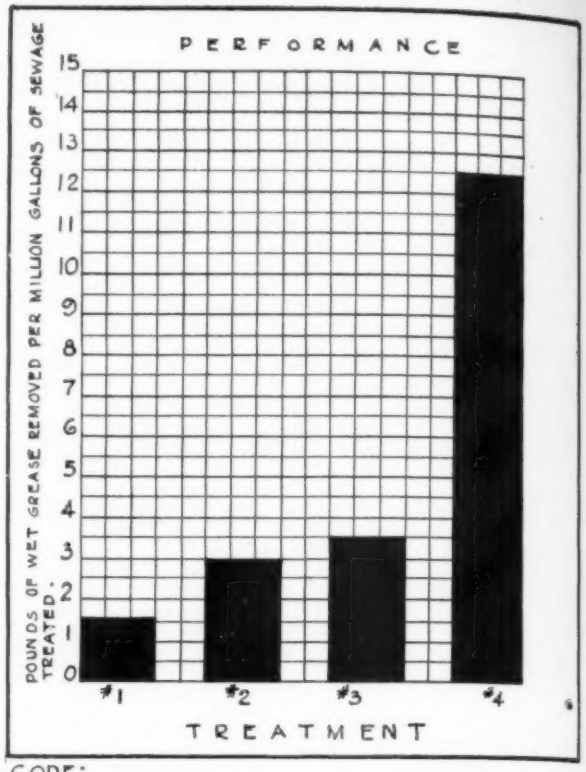
TABLE I
AERO-CHLORINATION VS. AERATION ALONE

Date (1937) August	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
14	3.6	0.12	2.0	11.3
15	5.8	0.18	2.0	7.4
16	3.6	0.12	2.0	17.4
17	3.5	0.11	2.0	16.2
18	3.2	0.11	2.0	10.9
19	2.9	0.10	2.0	11.2
20	2.9	0.10	2.0	12.5
21	2.9	0.09	2.0	10.6
22	2.3	0.08	2.0	5.6
23	2.6	0.08	2.0	18.3
24	4.0	0.13	2.0	14.1
Average	3.4	0.11	2.0	12.3
Composite Samples: (Grease content)		Raw Sewage 25 p.p.m.	Primary Effluent 6.0 p.p.m.	% Removal* 76

Date (1937) August	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
26	2.9	0.09	None	4.9
27	2.9	0.09	None	4.3
28	3.0	0.10	None	2.2
29	4.0	0.13	None	1.6
30	2.9	0.09	None	6.1
31	2.6	0.09	None	4.8
Average	3.1	0.10	None	4.0
Composite Samples: (Grease content)		Raw Sewage 19 p.p.m.	Primary Effluent 9.0 p.p.m.	% Removal† 53

*On the basis of pounds of wet grease removed, per million gallons of sewage treated, Aero-Chlorination increased the grease removal 308%.

†On the basis of the analyses of raw sewage and primary effluent an increment of 23% is noted for the removal of grease using Aero-Chlorination over the use of aeration alone.



CODE:
#1. TREATMENT WITHOUT AERATION AND WITHOUT CHLORINE.
#2. AERATION ALONE.
#3. CHLORINATION ALONE.
#4. AERO-CHLORINATION.

Controlled Check Tests—3 Methods

In February, 1938, due to the interruption of plant operations caused by the presence of excessive quantities of gas wastes in the sewage; it was possible to maintain fairly constant operating conditions over a period of time for experimental observations of the performance of Aero-Chlorination. The sewage flow was maintained at 4.0 M.G.D., giving a constant value for detention period and air applied. Chlorine was applied at 2.0 p.p.m. A five-day test was made February 17th to 21st, using treatment without pre-aeration and without chlorine. Another five-day test was made March 4th to 9th, using pre-aeration treatment alone. A third test was made March 16th to 21st, using Aero-Chlorination. The results of these measurements under rather constant conditions are shown in Table III. On the basis of pounds of wet grease removed per million gallons of sewage treated, aeration *alone* increased grease removal 187% over the treatment without aeration and without chlorine; Aero-Chlorination increased the grease removal over aeration alone by 417%; and Aero-Chlorination increased the grease removal 781% over the treatment without aeration and without chlorine. Laboratory analytical results showed 38% grease removal, using treatment without aeration and without chlorine; 50% grease removal, using aeration alone; and 80% grease removal, using Aero-Chlorination.

The grease determinations on the raw sludge and the scum removed are reported for these experimental periods in Table IV.

Chlorination Alone

Experimental measurements were made, using chlorination alone for grease separation on three successive Mondays and three successive Wednesdays during July, 1938. These measurements were made at the suggestion of H. A. Faber of the Chlorine Institute. The results appear in Tables V, VI, and VII. Mondays and Wednesdays were the days selected for these measurements because experience showed that the raw sewage has a maximum grease content on Mondays and an average grease content on Wednesdays. The chlorine dosages were 2.0 p.p.m. The experimental conditions as to the dosing of chlorine and plant operation were parallel to the experimental conditions during the previous measurement periods, using Aero-Chlorination, aeration alone, and the treatment without aeration and without chlorine. The appearance of the grease collecting on the primary tanks were visibly present in smaller quantities than during the treatment using Aero-Chlorination. On the basis of

pounds of wet grease removed per million gallons of sewage treated, chlorination *alone* increased the grease removal 219% over the treatment without aeration and without chlorine; and chlorination *alone* increased the grease removal 117% over the treatment using aeration *alone*. However, Aero-Chlorination increased the grease removal 371% over the treatment with chlorination alone. These comparisons are made, using the average of the results reported in July, 1938, and the results reported in February and March, 1938. The analytical results showed chlorination alone removed 41% of the grease. The grease analyses of the raw sludge and the grease collected are reported in Table VII.

Improvement in Activated Sludge Noted

The grease content of the activated ("return") sludge has been determined at frequent intervals since Aero-Chlorination has been in use. The grease content of the "return sludge" at the South Plant has been reduced between 64% and 74%. To our mind, this improvement has been due to Aero-Chlorination. These results are shown in Table VIII.

TABLE II

AERO-CHLORINATION VS. AERATION ALONE

Date (1937) Sept.	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs /M.G.
5	3.1	0 09	2 0	6.5
6	3.5	0.11	2.0	15.7
7	2.9	0.10	2.0	17.1
8	2 9	0.10	2.0	12.4
9	2.9	0.10	2.0	16.8
10	3.5	0.11	2.0	18.5
11	4.1	0.13	2.0	11.4
12	4 3	0.14	2.0	5.9
13	3.9	0.12	2.0	18.0
14	4 3	0.13	2.0	14.5
15	5.8	0 18	2.0	15.2
Average	3.7	0.12	2.0	13.8

Composite Samples: (Grease content)	Raw Sewage 23 p p.m.	Primary Effluent 5.0 p.p.m.	% Removal* 78

Date (1937) Sept.	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs /M.G.
20	3.8	0.12	None	4.3
21	3.5	0.11	None	3.4
22	3.5	0.11	None	4.1
23	3.9	0.12	None	2.6
24	3.3	0.10	None	3.5
25	3 2	0.10	None	4.3
26	3.9	0.12	None	2 8
27	3.4	0.10	None	5.7
28	3.4	0 10	None	3.8
29	3.4	0.10	None	2 3
30	3.4	0.10	None	4.4
Average	3 5	0.11	None	3.7

Composite Samples: (Grease content)	Raw Sewage 27 p.p m.	Primary Effluent 10.0 p.p.m.	% Removal† 63

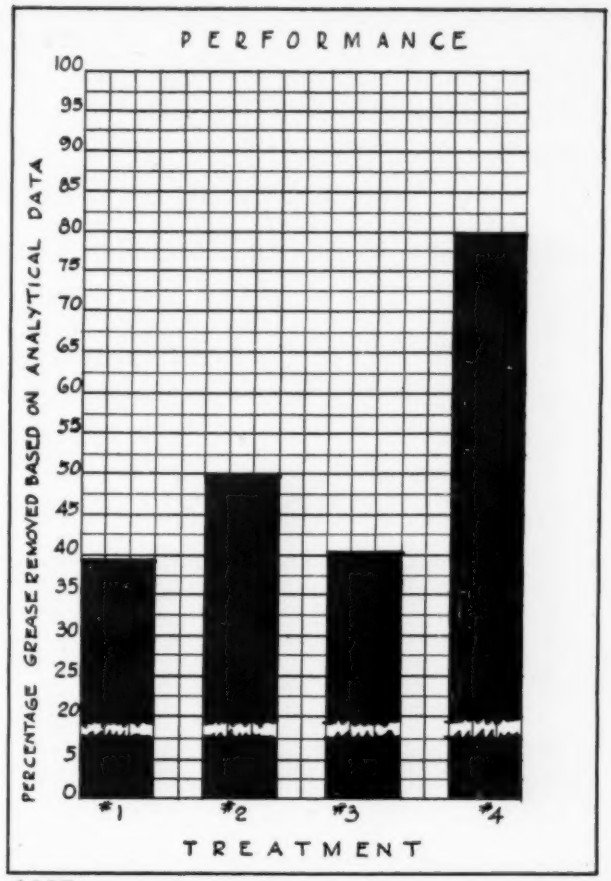
*On the basis of pounds of wet grease removed, per million gallons of sewage treated, Aero-Chlorination increased the grease removal 373%.

†On the basis of the analyses of raw sewage and primary effluent an increment of 15% is noted for the removal of grease using Aero-Chlorination over the use of aeration alone.

TABLE III

THREE METHODS COMPARED

Date (1938) February	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs /M.G.
17 (Thursday)	4.3	None	None	1.3
18 (Friday)	4.3	None	None	1.9
19 (Saturday)	4.3	None	None	0.9
20 (Sunday)	4.3	None	None	2.1
21 (Monday)	4.3	None	None	1.6
Average	4.3	None	None	1.6



CODE:
#1. TREATMENT WITHOUT AERATION AND WITHOUT CHLORINE.
#2. AERATION ALONE.
#3. CHLORINATION ALONE.
#4. AERO-CHLORINATION.

Composite Samples: (Grease content)	Raw Sewage 21 p.p.m.	Primary Effluent 13.0 p.p.m.	% Removal* 38

Date (1938) March	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
4 (Friday)	4.3	0.14	None	3.1
5 (Saturday)	4.3	0.14	None	2.9
6 (Sunday)	4 3	0.14	None	2.6
7 (Monday)	4.3	0.14	None	2.0
8 (Tuesday)	4.3	0 14	None	3.1
9 (Wednesday)	4.3	0.14	None	4.4
Average	4.3	0.14	None	3.0

Composite Samples: (Grease content)	Raw Sewage 26 p.p.m.	Primary Effluent 13.0 p.p.m.	% Removal* 50

*On the basis of pounds of wet grease removed, per million gallons of sewage treated, aeration increased the grease removal 187%. Aero-Chlorination increased grease removal over aeration

Date (1938) March	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
16 (Wednesday)	4.3	0.14	2.0	10.4
17 (Thursday)	4.3	0.14	2.0	13.2
18 (Friday)	4.3	0.14	2.0	12.9
19 (Saturday)	4.3	0.14	2.0	15.3
20 (Sunday)	4.3	0.14	2.0	7.5
21 (Monday)	4.3	0.14	2.0	15.7
Average	4.3	0.14	2.0	12.5

Composite Samples: (Grease content)	Raw Sewage 21 p.p.m.	Primary Effluent 4.0 p.p.m.	% Removal† 80

alone 417%. Aero-Chlorination increased grease removal 781% over the treatment without aeration and without chlorine.

†On the basis of analyses of raw sewage and primary effluent an increment of 12% is noted for the removal of grease using aeration, over the treatment without aeration and without chlorine. An increment of 30% is noted using Aero-Chlorination over aeration alone. An increment of 42% is noted, using Aero-Chlorination over the treatment without aeration and without chlorine.

TABLE IV
GREASE CONTENT OF PRIMARY SLUDGE AND SCUM

Date 1937—	Treatment	Raw Sludge Pct.	Scum Pits Pct.
Aug. 14-24	Aero-chlorination	27.56*	14.65*
Aug. 26-31	Aeration alone	32.08	12.69
Sept. 5-15	Aero-chlorination	25.67	16.34
Sept. 20-30	Aeration alone	31.17	14.19
1938—			
Feb. 17-21	Without aeration and without chlorine	31.19	10.17
March 4- 9	Aeration alone	30.08	11.19
March 16-21	Aero-chlorination	26.68	12.87

*Grease as determined by Standard Methods of Analysis—A.P.H.A.

TABLE V
PRE-CHLORINATION ALONE

Date (1938) July	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
11 (Monday)	4.1	None	2.0	2.7
13 (Wednesday)	3.7	None	2.0	1.9
18 (Monday)	3.4	None	2.0	4.7
20 (Wednesday)	3.4	None	2.0	3.1
25 (Monday)	3.4	None	2.0	4.8
27 (Wednesday)	2.9	None	2.0	4.0
Average	3.5	None	2.0	3.5*
Maximum	4.1	None	2.0	4.8
Minimum	2.9	None	2.0	1.9

*On the basis of pounds of wet grease removed, per million gallons of sewage treated, the treatment using chlorination alone increased the grease removal 219% over the treatment without aeration and without chlorine. The treatment using chlorination alone increased the grease removal 117% over the treatment using aeration alone. These comparisons are made using the average of the results reported in July, 1938, and the results reported in February and March, 1938.

TABLE VI
PRE-CHLORINATION ALONE
(Grease Content in p.p.m.*)

Date (1938) July	Raw Sewage	Primary Effluent	% Grease Removal
11	16	11	31
13	12	7	41
18	21	13	38
20	18	10	44
25	23	11	52
27	17	10	41
Average	18	10	41
Maximum	23	13	52
Minimum	12	7	31

TABLE VII
PRE-CHLORINATION ALONE
(Grease Content—Dry Basis*)

Date (1938) July	Raw Sludge Pct.	Scum Pits Pct.
11	31.63	13.09
13	28.65	12.39
18	35.09	15.37
20	36.11	14.29
25	34.61	14.86
27	33.96	15.10

*By Standard Methods of Analysis—A.P.H.A.

TABLE VIII
QUALITY OF ACTIVATED ("RETURN") SLUDGE

Date	April (1937)	May (1938)	July (1938)	August (1938)
Per cent grease*	21.63	7.78†	6.56†	5.61†
Per cent total solids	0.82	1.02	1.54	1.42
Per cent volatile solids	74.21	77.74	79.32	79.67

*Petroleum ether extraction by Standard Methods.

†Percentage reduction of grease content of Activated ("Return") Sludge:

	Pct.
April, 1937, to May, 1938	64
April, 1937, to July, 1938	70
April, 1937, to August, 1938	74

Discussion and Summary

The grease content of "return sludge" may determine the efficiency of the aeration of sewage sludge mixtures. It is believed that the presence of grease and oils in the "return sludge" and the sewage sludge mixtures do not permit the balancing of rate of oxygen utilization, because the grease and oils spread a protective film on the sewage and sludge particles, making intimate contact, and resulting oxidation slow and incomplete. Also, the absorption of the colloidal matter present in the sewage by the "return sludge" is not complete in the presence of grease and oils, because of this protective film. Aero-Chlorination of the raw sewage for grease removal does reduce the grease content of the sewage and sewage sludge mixtures to a marked degree; thereby, bringing the rate of oxygen utilization into a proper balance. The results at Lancaster show that Aero-Chlorination reduced the grease content of the raw sewage to the extent of 80%.

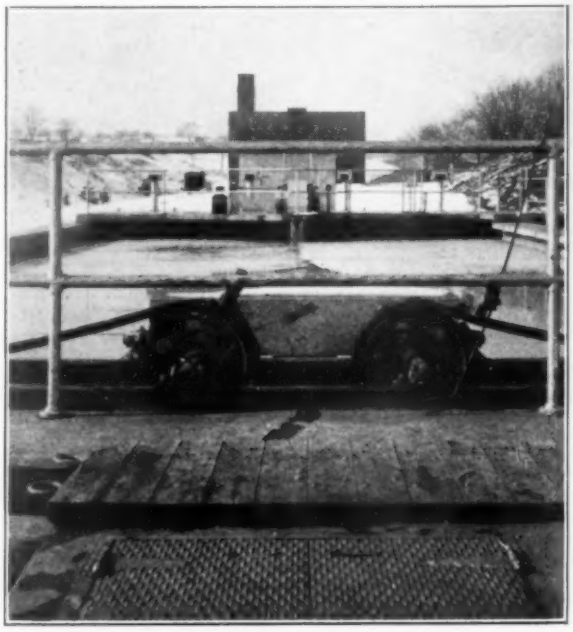
As the result of our tests and study of benefits derived, Aero-Chlorination has been made an operating feature at both of the sewage treatment plants of Lancaster. Since introducing Aero-Chlorination, the South Plant in Lancaster has experienced its first six months of continuously successful operation of the activated sludge phase of treatment. A high quality effluent has been consistently produced for the past six months, with a continuous and pleasing absence of "bulking" troubles.

Acknowledgment is made to L. H. Enslow and H. A. Faber of Chlorine Institute for their helpful suggestions and guidance.

The Department of Streets and Public Improvements is responsible for the management of the Lancaster Sewage Treatment Works. J. A. Taylor, Director; J. H. Shertzer, City Engineer; and E. J. Rhoads, Superintendent.

References:

[1]H. A. Faber, Water Works & Sewerage, 84, 171 (1937).
[2]Keefer & Cromwell, Water Works & Sewerage, 85, 97 (1938).



Primary Sedimentation Units

TRADE DOW MARK

FERRIC CHLORIDE

60% CRYSTALS — 37-47% SOLUTION

FOR SLUDGE CONDITIONING

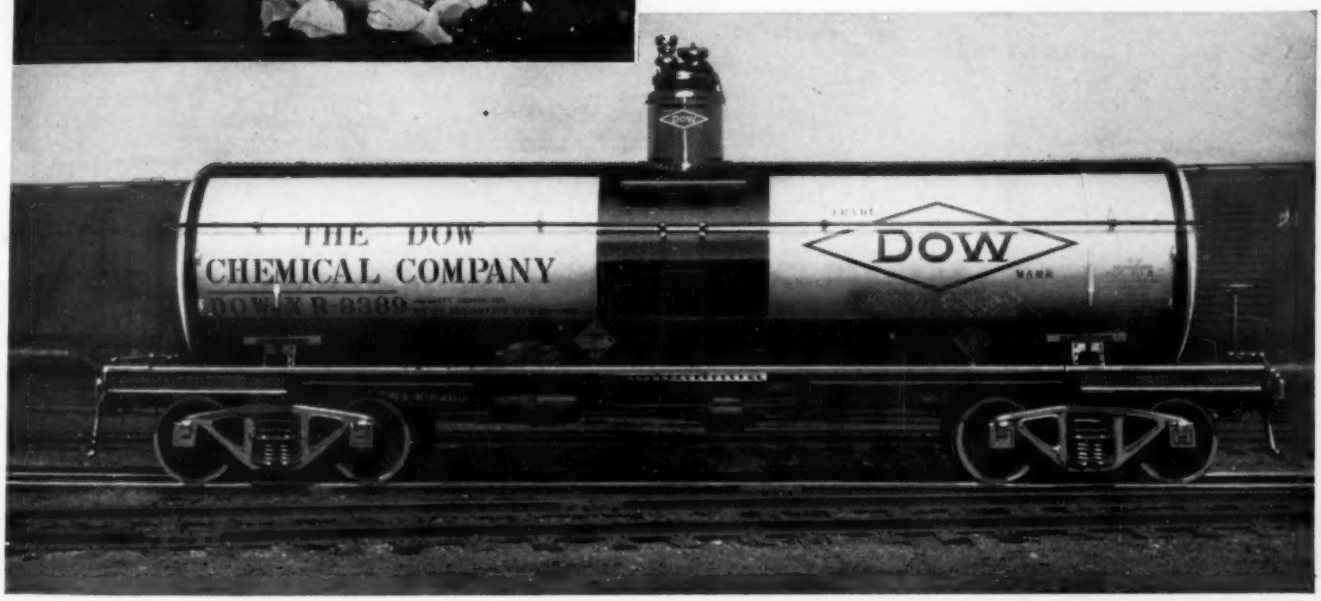
- Minimum chemical and operating costs.
- Cuts dewatering equipment cost — increases performance.
- Gives higher filtration rate.

FOR SEWAGE COAGULATION

- Greater removal of suspended solids.
- Lower 5-day B.O.D.
- Increased flexibility to meet peak loads and low stream flows.
- Economical effluent improvement.
- Reduction of hydrogen sulphide odors.

FOR WATER TREATMENT

- Forms a compact, quick settling floc with complete precipitation at any pH value above 5. Retains effectiveness in cold weather.
- Effectively removes large quantities of coloring matter. Precipitates tannin compounds at pH of 5 or below.
- In conjunction with lime, removes iron and manganese.
- Reduces taste and odor by removing H_2S.



Dow Ferric Chloride 37-47% Solution is shipped in tank cars. Ferric Chloride 60% Crystals are packed in 300 lb. and 500 lb. heavy wooden barrels, permitting storage without deliquescence of the crystals.

Dow Technical Service covering design and operating problems of sewage disposal plants is available upon request to engineers.

THE DOW CHEMICAL COMPANY

MIDLAND, MICHIGAN

NEW YORK CITY • ST. LOUIS • CHICAGO • SAN FRANCISCO • LOS ANGELES • SEATTLE • HOUSTON

They Save With

TENNESSEE CORPORATION
Ferri-Floc
FERRIC SULPHATE

FERRI-FLOC is the ferric coagulant that is today solving water and sewage problems throughout the United States. In actual plant operations **FERRI-FLOC** is proving most satisfactory for use under widely varying conditions.

In water treatment, the use of **FERRI-FLOC** varies from simple coagulation at normal pH's to softening at high pH's, and color removal at very low pH's.

In sewage plants, **FERRI-FLOC** is being used at high pH values for treatment of concentrated laundry wastes, at extremely low pH values for slaughter house wastes, and at practically all intermediate pH's for treatment of domestic sewage, milk wastes, canning plant wastes, acid wastes, and a multitude of others.

The purity of **FERRI-FLOC** has not only been maintained during present adverse conditions but has actually been improved.

The following table gives a cross-section of the water and sewage plants now using **FERRI-FLOC**, and an idea of the varied problems which have been successfully solved through its use.

PROBLEMS SOLVED BY FERRI-FLOC IN WATER TREATMENT PLANTS

ANDERSON, IND.	CINCINNATI, O.	DALLAS, TEXAS	DALTON, GA.	KANSAS CITY, MO.
Highly polluted surface water with special color, taste, and odor problems.	Large storage hoppers allowed caking, and "smoke" was present in settled water.	Short filter runs and relatively high cost of secondary coagulation.	A highly variable mountain stream coupled with demands for a uniformly soft finished water presented a seemingly impossible problem.	Coagulation and softening of Missouri River water without recarbonation facilities.

PROBLEMS SOLVED BY FERRI-FLOC IN SEWAGE TREATMENT PLANTS

ANNAPOLIS, MD.	ATLANTA, GA.	CELINA, OHIO	ELWOOD, IND.	HOUSTON, TEX.
Sludge filtration costs were excessive. (These costs were cut about 80%.)	Sludge filtration costs were too high. (These costs were cut about 60%.)	Cannery, milk, acid and domestic wastes —Raw BOD as high as 1800 ppm—Very small receiving stream.	Cannery wastes and domestic sewage — Raw BOD often over 1000 ppm — Very small receiving stream.	Concentrated brewery wastes grossly polluting small stream.

Take advantage of modern plant research and findings: let FERRI-FLOC solve your water or sewage treatment difficulties. Ask Tennessee Corporation's Technical Staff to help you solve your specific problems, or write for case histories of plants with problems similar to yours.

TENNESSEE CORPORATION

ATLANTA, GEORGIA **LOCKLAND, OHIO**

IMPROVING THE OPERATION OF A SMALL TREATMENT PLANT

Wherein Inexpensive Contrivances Have Played an Important Part

By C. G. WEBER
Superintendent
Sewage Treatment Works, Annapolis, Maryland

THE Sewage Treatment Works, of Annapolis, having a capacity of 3 M.G.D., was placed in operation on September 4, 1936. The treatment consists of coarse screening, pre-chlorination and primary sedimentation with separate sludge digestion in heated fixed cover digesters. The sludge is dewatered on vacuum filters.

The sewage flows by gravity to a pumping station where it receives pre-chlorination. It is then pumped through a force main to the treatment works about one mile from the pumping station.

The treatment works consists of two 150,000 gallon clarifiers, provided with sludge removal and grease skimming mechanisms; two 180,000 gallon fixed cover sludge digesters, provided with gas collection and heating coil systems; a vacuum sludge filtering system; and a fully equipped control laboratory.

Chlorination Improvements

Chlorine was originally applied to the raw sewage at a manhole on the interceptor 25 feet ahead of the pumping station and into two 10,000 gallon wet wells (Fig. 1). With this arrangement there was considerable loss of chlorine which was not absorbed by the sewage. Chlorine permeated the shredder room and other parts of the pumping station causing considerable damage to metal parts. Applications of chlorine at the rate of 20 p.p.m. seldom produced chlorine residuals in the clarifier effluents and residuals in the influent reaching the plant were not at all uniform. Furthermore, there was rapid accumulation of sewage solids in the center of each wet well which increased the chlorine demand as it accumulated. Several feet of solids would accumulate in two or three days.

To overcome these difficulties the chlorine solution was piped to the wet wells and applied behind a deflector placed in the wells as shown in Fig. 1. By thus changing the direction of flow of the sewage through the wells the solids were prevented from accumulating. Chlorine, applied as shown at the baffle, was thoroughly mixed with the sewage and uniform residuals appeared at the treatment plant, with chlorine dosages of 15 p.p.m. Whereas, formerly there was little or no correlation between chlorine applied and chlorine residuals, complete correlation now exists and chlorine gas is no longer noticeable in the pumping station.

There are two W & T vacuum type automatic chlorinators, the water supply for which is obtained from the Severn River. When the temperature of the water drops to 47° F. the formation of chlorine hydrate has created considerable operating difficulty.

A 1,000 watt heater placed inside the chlorinator was helpful but not entirely satisfactory and very expensive to operate.

A hot water coil installed in the recirculating line of our hot water boiler, worked perfectly. During the past winter water pumped from directly under the ice was used without any difficulty.

Improvised Grit Chamber

The sewage treatment plant is not provided with a grit chamber. As a result the digester and clarifier pipes became choked with grit, making it very difficult to withdraw a sludge from either unit. At one cleaning about 6 tons of grit was removed from the clarifiers. Grit also accumulated rapidly in the digester. The Annapolis system is one of those assumedly separate domestic systems.

At the influent of the plant there is a diversion chamber provided with a swing gate. Immediately in front of this gate I installed a steel dam, which made a very satisfactory grit trap (Fig. 2). The accumulated grit is removed daily, and for the past two years we have had no grit trouble.

Sludge Pumping

The withdrawal of raw sludge from the clarifiers was through two telescopic valves, into a sludge well. From the well the sludge was pumped to the digesters. Since the well was open to the air there were numerous complaints of odors therefrom during its use. Furthermore this method of removal required about six hours.

To eliminate these difficulties we removed the valves and piping and connected directly to the sludge pump suction lines, and we measure the pumpage in minutes. A gage, installed in the laboratory, indicates when the sludge is thick or too thin for further pumping.

Sludge Disposal

For disposal of the digested sludge the plant was equipped with a sludge storage tank 11′ 6″ long by 9′ 6″ wide and 10′ deep, inside dimensions. The available storage space was about 900 cubic feet. The sludge from this tank was pumped to a conditioning or ferric mixing tank, equipped with air diffusers for mixing the sludge with lime and ferric chloride. Lime was added from a lime feeder and ferric chloride was fed from an Omega Solution Feeder. The conditioned sludge then flowed to an Oliver Vacuum Filter having 65 sq. ft. filter area.

Chemical Requirements

For the first year of operations (1937), we used on a dry sludge solids basis 7.7% ferric chloride and 21% lime. As our anhydrous ferric chloride then cost $3.62 per hundred and lime cost 55 cents per hundred, our cost of chemicals per ton of sludge solids was $7.88.

We soon found that lime caused rapid cloth binding. After dewatering about 12 tons of dry sludge solids the filter cloth had

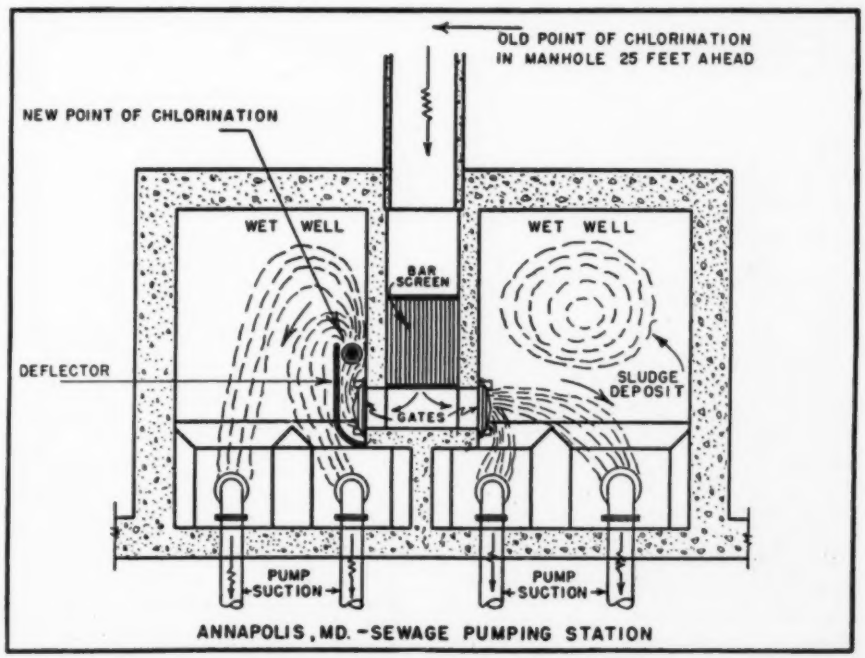


Fig. 1—Twin Pump Suction Wells
Before and After Installing Baffle, Which Prevents Sludge Accumulations and Chlorine Loss.

*A paper presented before the 15th Annual Meeting of the Maryland-Delaware Water and Sewage Works Association.

to be acid washed. This represented about 51 hours of actual filter service per cloth dressing.

In 1938 we substituted a mechanical stirrer in our conditioning tank in place of the air mixing method, and found that without any lime at all we could get good filtration when using 7.3% ferric chloride. This method increased our filter cloth life by 200%. That is we dewatered 36 tons of sludge solids, or got about 153 hours of actual service out of each filter dressing. This development reduced the cost of our chemicals per ton of digested solids to about $5.29 per ton of digested solids, a saving of $2.59 (33%). Added to this was the saving in filter cloth costs.

In 1939 we managed to get the ferric chloride consumption down to 4.6%. However, about half of the sludge filtered was partially elutriated, as, with permission of Mr. A. L. Genter of Baltimore (owner of elutriation patents), we started experimenting with sludge elutriation in our sludge storage tank during 1939.

Elutriation Experiences

Our first trials with partial elutriation showed such definite savings in chemicals, labor power and filter cloth that we arranged to change over to a better method of elutriating, and of dosing the elutriated sludge with coagulant; also a simpler and more direct method of feeding the dosed sludge to the Oliver Filter.

First of all this necessitated placing a sloping concrete bottom in the existing sludge storage tank for elutriation purposes. Without this bottom experiments had proved that we couldn't obtain at all times a sludge of uniform solid content from the flat bottomed tank for a complete filter run. I also found that the elutriated sludge coagulated so easily with ferric chloride or alum solutions that we could do away with the mechanical stirring.

Changing the bottom of the sludge storage tank and equipping it with a sludge and water mixing trough and swivel pipe for syphoning off the clear wash water or elutriate, after allowing the washed solids to settle out, reduced the available elutriation settling space to about 650 cubic feet. However, this did not handicap our operations, but greatly improved our economies.

Settled Sewage Proves Best

For the last six months I have been experimenting with elutriation and making various changes to get the best economies from this treatment with our very limited means. We tried elutriating with well water, brackish bay water and settled sewage from the Dorr Clarifier. The latter proved the most effective and least costly source of elutriate water for our sludge. The brackish bay water, nearest our plant, actually produced a wetter cake and required slightly more ferric chloride. This was somewhat contrary to expectations.

Arrangements

Our present set-up for elutriating and conditioning the digested sludge is shown in Fig. 2.

One of the telescopic sludge valves removed from the raw sludge well was placed in a 50 gallon steel drum on top of the sludge elutriation tank. When this valve is properly set by the hand-wheel there is just enough gravity head from the digestion tank to feed a steady stream of digested sludge into the drum. Settled sewage is pumped into the same drum, mixing with the digested sludge. The mixture then overflows a vertical pipe standing in the open drum and flows to the elutriation settling tank through a manhole on top of this tank. As the drawings show, the sludge and water are thoroughly mixed in a trough located in the top of the settling tank. The trough is equipped with baffles staggered at an angle. The mixture then flows into the tank, until it is practically full. After the solids have settled out, the clear supernatant is syphoned off by means of a 4-inch swivel overflow drain. This supernatant flows to the plant sump and is pumped back to the primary clarifier. The settled washed sludge is pumped to the conditioning tank, which will be described later.

In Fig. 3 is pictured the simple arrangement adopted for pumping elutriating water from the overflow trough of the primary Dorr clarifier through the window of the filter building to "washer tank" on top of the elutriation tank.

Results

At present we are dewatering elutriated sludge with about 1.7% ferric chloride and no lime. The price of ferric chloride has advanced from $3.62 per hundred in 1937 to $4.98 per hundred at present, or almost 38% increase. Despite this fact our present cost for ferric chloride per ton of sludge solids is but $1.69, which is $6.19 (78.5%) less per ton of sludge solids than in 1937 and $3.60 (68%) less per ton than in 1938.

To be entirely fair to our present elutriation results, if we were now paying the price of $3.62 per hundred for ferric chloride like in 1938, our present cost per ton of sludge solids

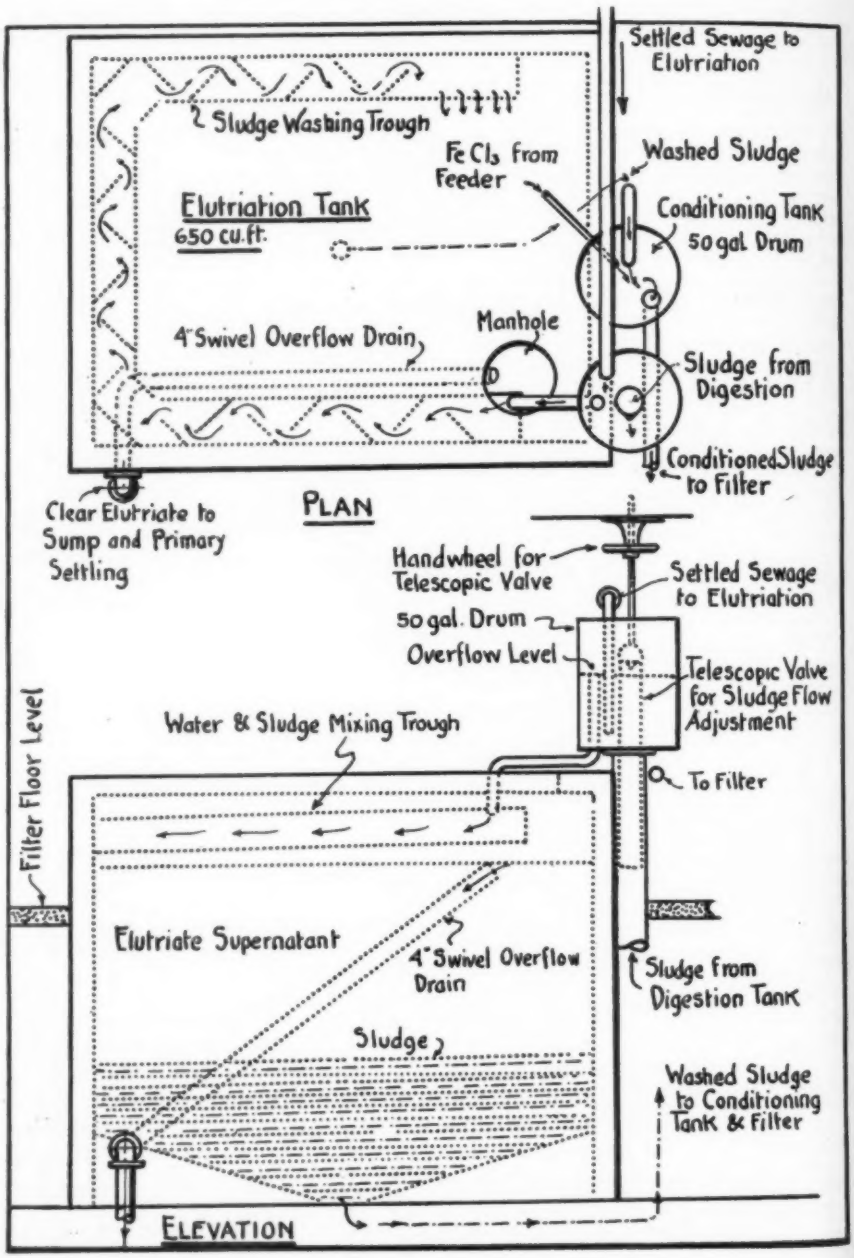


Fig. 2—Sludge Elutriation Arrangement
Sludge Storage Tank Converted Into Elutriator, Employing Settled Sewage as the Elutriating Water. Note Adjustable Mixing Tank at Top.

dewatered for ferric chloride would be $1.23 and the savings per ton of sludge solids dewatered would be $6.65, or 84.5% less than in 1937; and $4.06, or almost 77% less than in 1938.

However, with elutriated sludge at Annapolis there are other means of cutting chemical cost. We have made very successful filter runs on elutriated sludge when using commercial alum from our water treatment plant. Compared to anhydrous ferric-chloride, about three times as much commercial alum is required and the price of alum vs. ferric-chloride will determine the material to be used in the future. We tried alum on unelutriated sludge and found it unsatisfactory, as the conditioned sludge was difficult to filter and required much larger doses.

Other Savings

The savings in chemical costs are only a part of the story of elutriation economy. Our filter yields at this low chemical addition are from 8 to 10 pounds per square foot per hour and our filtering time, labor and electric current consumption has been cut in half. During 1939 when about half of our sludge was elutriated our filter blanket lasted for 123 tons of cake or over 520 hours of active service. We now hope to get 300 tons or about 1,200 hours of service out of a blanket costing about $27.

Sludge Mixing Arrangement

The details of our present sludge conditioning tank are shown in Fig. 4. This tank was made out of a 50-gallon oil drum and has no mechanical stirrer or air diffuser, so power for this purpose has been eliminated. By properly jetting the small stream of ferric chloride from the Omega Feeder into the inflowing stream of washed sludge, the sludge and ferric chloride or alum solution are thoroughly mixed. This is done by the agitation resulting from the inflowing sludge stream falling into the pool of sludge in the bottom of the small tank or drum. This pool is about seven inches deep and the inflowing stream displaces an equivalent amount out of the drum through a vertical pipe nipple overflow. This nipple can be lifted out of the drum at the end of filter runs so all of the conditioned sludge will be drained from the system to the filter.

With elutriated sludge this intimate flash mixing produces an excellent floc almost instantly. The conditioned sludge displaced from the drum flows downward through a feed pipe, through the end of the Oliver Filter tank to the center point without any delay. In other words the feed pipe is not the usual inverted syphon. We found that the inverted syphon was very unsatisfactory. Furthermore, feeding the sludge directly into one end of the filter resulted in good cake on half of the filter nearest

Fig. 3—Portable Homelite Pump
Delivers Settled Sewage to the Mixing "Washer Tank" (Fig. 3) at a Cost of 13c per Day.

the sludge inlet and poor cake on the other end of the drum. So we extended the pipe to the center.

In operating elutriation and filtration our set-up does not permit withdrawing clear elutriate while we are washing sludge because our settling tank is too small. However, as we filter sludge but two or three times every week, we draw the sludge from digester and wash it during the day preceding filtration. We then let the sludge settle over night, which produces a very clear elutriate and thick sludge. We syphon the elutriate off on the following morning and pump the settled washed sludge to

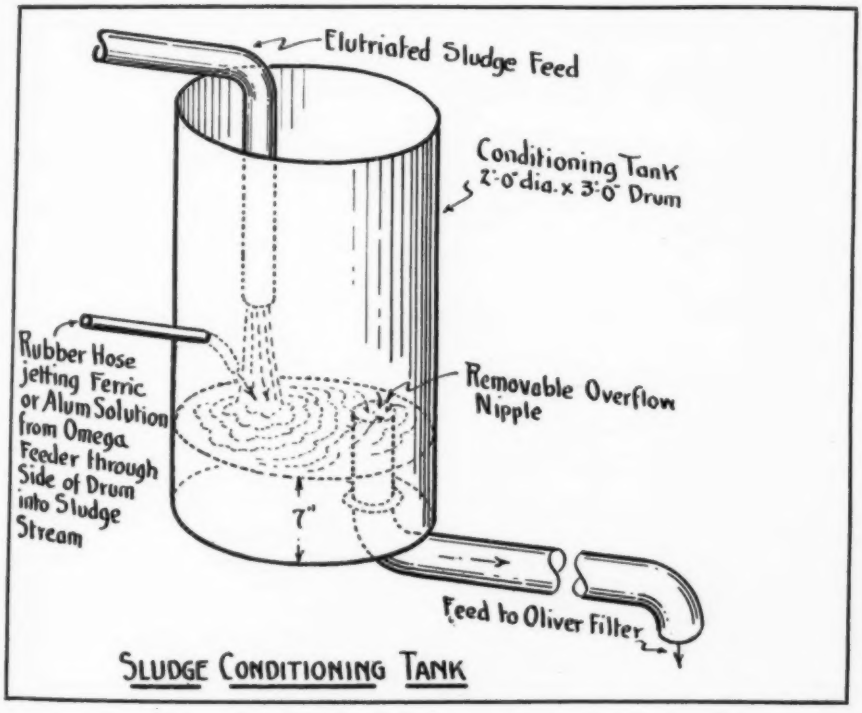

Elutriated Sludge Feed
Conditioning Tank
2'-0" dia. x 3'-0" Drum
Rubber Hose jetting Ferric or Alum Solution from Omega Feeder through Side of Drum into Sludge Stream
Removable Overflow Nipple
7"
Feed to Oliver Filter
SLUDGE CONDITIONING TANK

Fig. 4—Simple Sludge Conditioning Tank
From a 50-Gal. Oil Drum This Effective Mixing Unit Was Constructed. Seems to Be All That's Required for Elutriated Sludge.

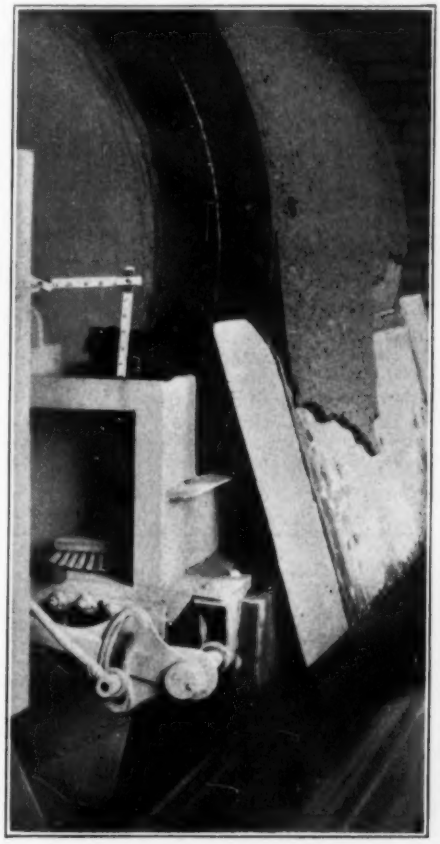


Fig. 5—Filter Cake
This ¾" Cake (8 to 10 lbs. dry solids/sq. ft./hr.) is Characteristic of Present Operations.

sludge conditioning and the filter. We generally use about four voulmes of elutriating water (settled sewage) to one volume of sludge. We filter about 2,200 pounds of sludge solids during one filter run and take about 3 hours to complete the run. Ordinarily we filter about 156 days every year, or three times a week.

Fig. 5 shows the filter cake now obtained from the elutriated sludge. Four cake thicknesses measure three inches, meaning the cake is about ¾" thick.

"Annapolis" Sludge Weigh-Recorder

Previous to the use of elutriation we had estimated the sludge solids dewatered by sampling the sludge collected in the storage tank and then measuring the cubic feet and pounds of sludge withdrawn from the tank by any filter run. When elutriation was adopted this method was not practical. I then devised an automatic self-dumping and recording sludge scale, shown in Figs. 6 and 7. The first is a sketch of this device. As can be seen this is controlled by adjustable weights, and the whole is attached to the supporting frame of the filter cake belt conveyor. At present this dumping scale is set, by the "adjusting weight" on the arm locking into the spring bolt, to release the hinged bottom door when exactly 33.3 pounds of sludge cake has accumulated in the scale box from the belt conveyor. The scale is frequently checked by diverting a dumped load to a pan on an ordinary beam scale. An ordinary revolution counter, fastened to the conveyor frame, is attached by a rod and spring to the weighted arm which closes the box bottom after each load is dumped into the truck below the box. The cake is sampled for moisture and solids determinations and by multiplying the number of cake dumps recorded on the counter by the weight of each dump and the percent solids present, the dry pounds of cake solids per run are easily obtained. The photograph (Fig. 7) shows this inexpensive and accurate device with the hinged door open above the plant truck.

Much for Little

All of the ideas, changes and labor relating to the foregoing changes in our treatment system were supplied by myself and others of the operating force. The cost of the materials and structural changes involved in elutriation, new sludge conditioning method and filter feeding and cake weighing amounted to less than fifty dollars.

The cost of pumping clarifier overflow (settled sewage), for elutriation with the little Homelite Portable Pump is very little, namely 13 cents per day of operation. This cost is more than offset by our saving in power for filtration.

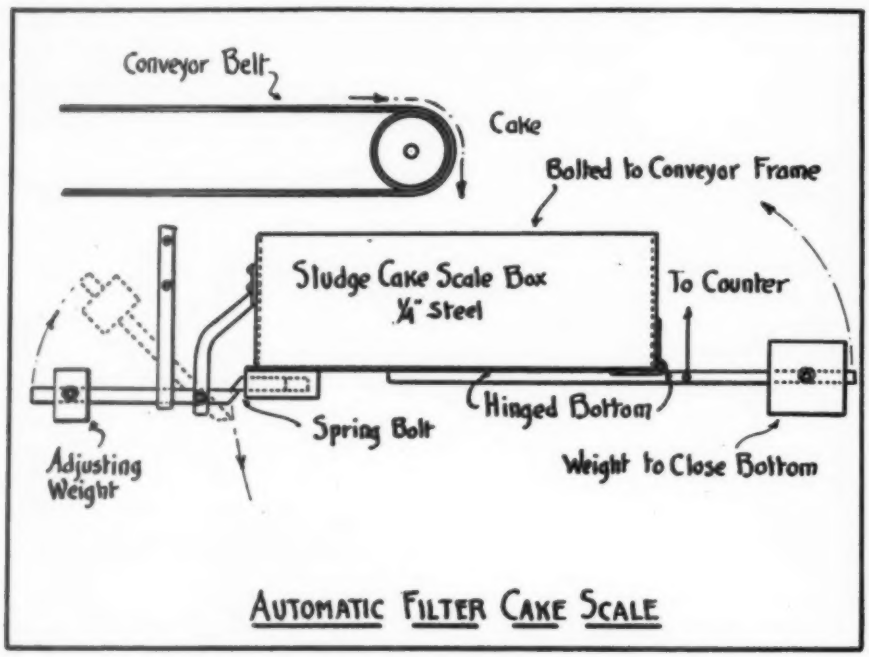


Fig. 6—"Annapolis" Automatic Sludge-Weigh-Recorder
Just a Home Made "Gadget," but It Does a Good Job of Giving Us a Record of Sludge Weight and Dumps Automatically—See Fig. 7.

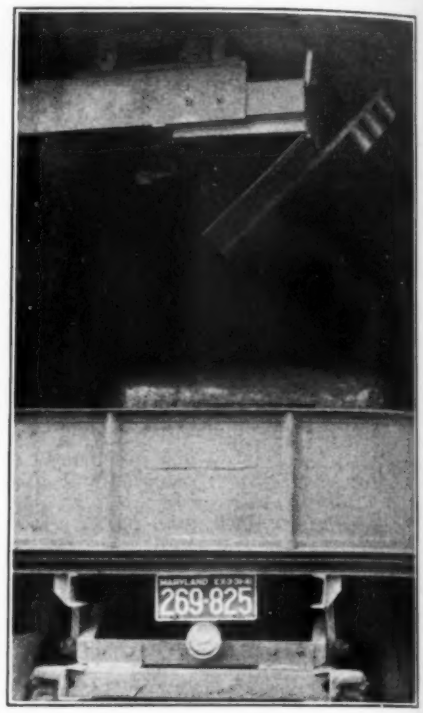


Fig. 7—The Self Dumping Weight-Recorder
Has Just Released Its Load of 33.3 lbs. of Filter Cake Into Truck—See Fig. 6.

KEEPING LIME SOLUTION LINES CLEAN

To retard building up of incrustation and depoits, which choke pipe lines conveying lime suspension, the following has been found very helpful at the Richmond, Va., Filter Plant. A program clock at 4 hour intervals opens and closes a flushing valve connected into the line at the inlet end. The line is thereby automatically scoured free of the loosely deposited carbonate and hydrate 6 times daily.

If a scale gradually builds up which the Richmond scheme of water scour will not remove, chlorine water from a chlorinator can be run through for the required period to dissolve or loosen the scale. Chlorine water applied to lime carbonate reacts to produce hypochlorous acid, carbon dioxide and calcium chloride as indicated by the reaction.

$$CaCO_3 + H_2O + 4\,Cl = 2\,HO\,Cl + CaCl_2 + CO_2$$

Pouring chlorine water slowly through a column of ground limestone or marble will demonstrate the reaction and is a well known method of preparing hypochlorous acid. The solution resulting, because of the weakness of the hypochlorous acid produced, has a pH of 8.0 to 8.2.

After the carbonate is all converted, chlorine water will naturally attack metallic solution lines. Lines of rubber hose with jointing made by butting hose ends together *inside* of a short sleeve of larger size hose, or a short section of pipe, provides a very satisfactory all purpose chemical feed line.

INNIS, SPEIDEN & COMPANY

117 Liberty Street NEW YORK, N. Y.

BOSTON CHICAGO CINCINNATI CLEVELAND GLOVERSVILLE PHILADELPHIA

Ferri-Clor AS A COAGULANT FOR SEWAGE AND INDUSTRIAL WASTES

The chemical treatment of sewage and industrial wastes is an effective and economical method of increasing the efficiency of the ordinary sedimentation plants. Such treatment requires but little plant construction or capital investment. It provides a high overload capacity and flexibility in proportioning to produce the degree of purification required. Seasonal loads are readily handled with the Ferric Chloride treatment.

Ferric Chloride coagulates sewage and industrial wastes. thus causing more rapid precipitation in sedimentation plants and faster filtering through vacuum filtration systems. It is most effective in the pretreatment of industrial wastes which offer change in characteristics almost hourly.

Experience has shown that Ferric Chloride is also an *economical* coagulant for sewage and wide range of industrial wastes.

FOR COAGULATING SEWAGE

Ferric Chloride provides an inexpensive and efficient method of dealing with plant overloads, and reduces original plant investment by increasing the capacity of the sedimentation plant.

Amount of Ferri-Clor to Be Used

The accepted procedure in determining the dose of Ferric Chloride required to coagulate a given sewage is to set up "jar tests" with sewage to be tested. 2 qt. Mason Jars and stock solutions of Ferric Chloride and Lime, consisting of 10 grams per liter of distilled water, are used. Place one liter of sewage to be tested in each of several Mason Jars. Add to the sewage in each jar, successively larger doses of Ferric Chloride stock solution. Stir all samples thoroughly for several minutes and let stand for 1 hour. Observation of the several samples will determine the best dosage. If lime is required to provide sufficient alkalinity for satisfactory coagulation, follow the same procedure outlined for Ferric Chloride. The amount in lbs. of Ferric Chloride or Lime required equals the number of c.c. used in the selected test × 10 × total sewage flow (m.g.d.) × 8.33.

FOR SLUDGE CONDITIONING

Ferric Chloride is accepted as the agent most efficient from the standpoint of performance and cost for the coagulation of sludge prior to its dewatering in the filter.

Amount of Ferric Chloride to Be Used

Using the Buchner Funnel Test, the time periods required for the vacuum to break with varying quantities of coagulant are recorded. 2 to 3 minutes is satisfactory and 1 to 1½ minutes is very good and should be used for plants where the sludge is held as in batch-mixing.

Various combinations of Ferric Chloride and Lime should be tested until the relative quantities for optimum operation are determined.

ISCO FERRIC CHLORIDE

The approximate quantities of chemical to be used in the plant can be determined from the laboratory tests, provided, of course, that the same strength chemicals are used in the plant. The quantity of Ferric Chloride solution in gallons per 1000 gallons of sludge will be 5 times the c.c. used per 200 c.c. of sludge in the test. Likewise, the quantity of Lime in pounds per 1000 gallons of sludge will be 42 times the grams used per 200 c.c. of sludge.

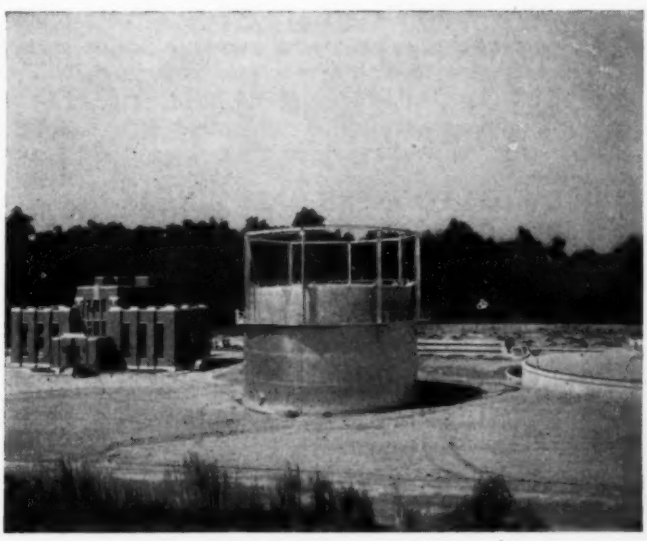
PREPARATION OF FERRIC CHLORIDE SOLUTION

The main difficulty in dissolving Ferric Chloride arises from the fact that the saturated solution is heavier than water. This means that the liquid in a simple container may have a layer of pure water at the top, even with undissolved crystals at the bottom. To overcome this difficulty, three methods have been developed.

1. Automatic gravity circulation by placing the salt on a wooden grid elevated or suspended one-half way in the tank.
2. Mechanical mixing by (a) stirring, (b) by air agitation, and (c) liquid recirculation.
3. Belting: Ferric Chloride melts at 98.6 to 102.2°F. and so can readily be liquefied by relatively small amounts of heat from exhaust or live steam, flue gases, oil, gas or electricity. The dissolved salts can be poured into the water.

Ferri-Clor 60% ($FeCl_3$)

is ISCO's registered name for Ferric Chloride developed and manufactured especially for Sewage and Water Treatment Use.



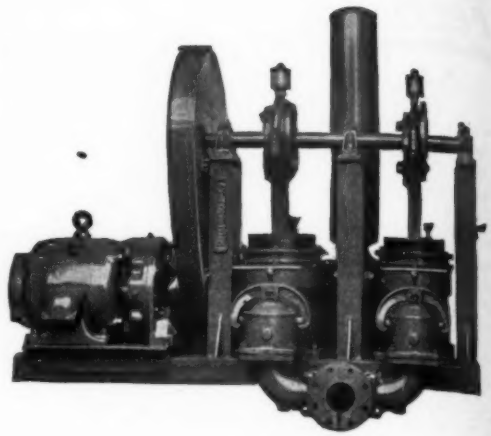
ISCO Ferric Chloride is used in America's newest and most modern sewage treatment plants.

RALPH B. CARTER COMPANY

Hackensack, New Jersey

EQUIPMENT FOR SEWAGE TREATMENT AND WATER PURIFICATION

CARTER SLUDGE PUMPS

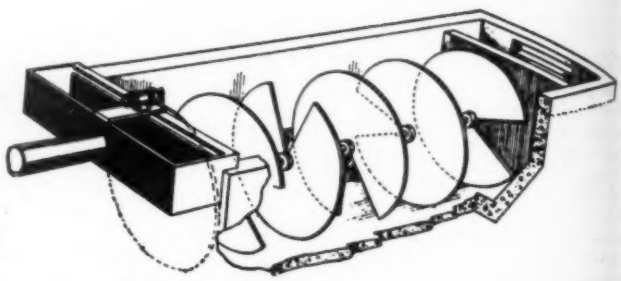


The installation of Carter Sludge Pumps in a large majority of today's modern sewage plants is proof of established merit. Exclusive features include: Flanged connections throughout the pump; renewable valve seats; successful elimination of all pump pound by an adjustable automatically maintained air cushion in the pump cylinder; babbitt lined eccentrics; properly balanced fly-wheel on the main shaft; chain drive and herringbone reducing gears.

Capacity control by adjustable eccentric drive, by variable speed transmission enclosed with the motor housing, or by variable speed, slipring motor.

Capacities from 31.8 to 382.2 GPM, heads from 50 to 115 ft.

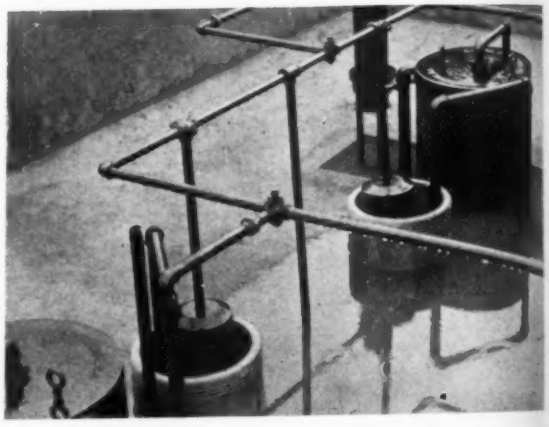
CARTER IMPROVED FLOCER—WITHOUT PADDLE AGITATION



Exclusive features include: 10% to 25% shorter Detention Period; low cost installation and maintenance; negligible power consumption.

Unit is constructed with a series of flat discs, each with a segment removed. Mechanism is slowly rotated and agitation is set up by flow of liquid through the open segments. Settling occurs between discs during the travel of the open segment in the upper half of rotation. Flocs therefore are not cut up, enabling the formation of a floc of sufficient size to settle rapidly, by the time the mixture passes into the settling tank.

ALTERNATING SYPHONS



For filter beds in a complete range of sizes from 6" to 14". Fully automatic in operation.

Designed for trouble free operation and guaranteed to give a quick uniform distribution in alternate cycles, the Carter siphon has proven itself as equipment worthy of consideration on your next sewage treatment plant.

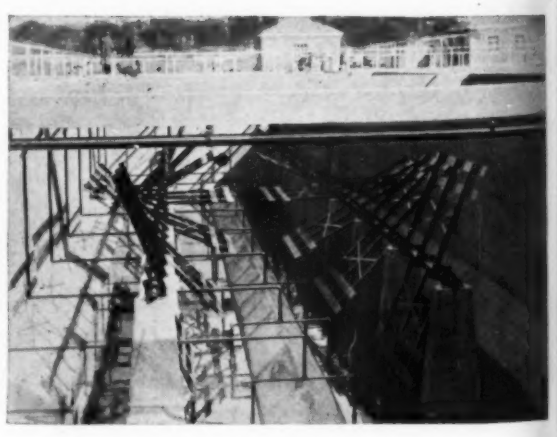
"HUMDINGER" PORTABLE SELF-PRIMING CENTRIFUGAL PUMPS

The only patented priming control guaranteeing 28' suction lifts. A complete line of dewatering pumps including 2", 3", 4", 6" and 8" units. Invaluable for general plant usage. Successfully used for pumping out Imhoff and other type settling tanks, breaking scum, or washing down tank sides.

SLUDGE CONDITIONERS AND MIXERS

Consult Carter engineers to assure the effective mixing required for proper digestion of sludge. Standard and Pump type rapid mixers also are built for chemical treatment.

PADDLE TYPE FLOCERS AND AERATORS



Certain conditions require increased air diffusion in activated sludge treatment. The Ralph B. Carter Company manufactures a full line of paddle mechanisms. Careful design of shaft and bearings assure long trouble-free life under the necessarily difficult underwater operating conditions.

Illustration shows Carter Type Aerators installed in an activated sludge sewage treatment plant. Units designed to handle a maximum flow of 6.0 M.G.D.

SEWAGE AND SLUDGE PUMPING

By HENRY RYON
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State Department of Public Works, Albany, N. Y.

Part I—Sewage Pumping

During the past several years a very marked improvement has been made in the methods of pumping sewage and sewage sludge, and special pumps have been developed for this service. Only a few years ago, however, practically all sewage was lifted with pumps designed primarily for handling water.

The centrifugal dredging pump driven either by a steam engine or an electric motor was used with a fair degree of success at many stations. While this pump would handle sand and gravel satisfactorily, rags would wrap themselves around the impeller and necessitate frequent cleaning of the pump either through hand holes in the volute or by the removal of the side of the case. It was not very efficient and the head was limited. The smaller and higher speed centrifugal pump, used successfully for pumping water, gave more trouble, due to clogging, when used for pumping sewage, than the dredging pump.

Reciprocating pumps were used in many cases. These pumps clogged about as easily as the centrifugal pumps; and, if there were any sand or grit in the sewage, gave trouble due to the scoring of cylinders. At one or two large stations the crank and fly wheel pump was used and operated satisfactorily principally because of its large size. The ordinary duplex steam pump served in a few cases. The single acting triplex pump, equipped with ball valves, although not entirely free from clogging, proved to be the most satisfactory of the reciprocating pumps and was used, and is still being used, successfully for pumping both sewage and sludge. Its cost is, however, greater than that of a centrifugal pump and it is rather noisy. It is worth noting that the design of the most modern reciprocating sludge pumps have apparently been copied from the old single acting triplex pump.

At almost all of the old pumping stations the sewage was passed through bar or mesh screens to remove the rags and other solids from it before it reached the pumps. The cleaning of the screens always proved a laborious and unpleasant task, and did not entirely do away with the necessity of cleaning the pumps.

The Pneumatic Ejector

In order to eliminate the trouble of cleaning screens and pumps, the pneumatic or compressed air ejector was developed. This device, which was first used about fifty years ago, operates by allowing the sewage to flow into an iron or steel chamber and, when the chamber is full, automatically admits compressed air above the sewage thus forcing it out through the discharge line. The mechanism operates very successfully, and stories are told of ejectors having been lost for several years and when rediscovered were found to be operating satisfactorily. It requires, however, air compressors, air tanks, and other appurtenances which make the first cost and also the maintenance expensive. In addition to this, the efficiency is very low. The overall or wire to water efficiency when the compressors are operated by electricity vary generally from 10 to 20 per cent. At present, due to the improvements in the design of centrifugal pumps, ejectors are being used less and less except in the very small stations or for sludge and screenings handling.

Pump Impellers

The improvement in the centrifugal sewage pumps has been largely in the design of the impellers or runners. There are, in general, two types of pump impellers, the open and the closed. The open impeller gives larger water ways with the same size casing, but solids clog between the impeller and the casing and rags wrap around the impeller blades. Increasing the clearances to reduce clogging, of course, reduces the efficiency and does not prevent rags from stopping the flow. Open impellers, generally with only two blades, serve well in small sump pumps and also in sewage pumps of small capacities where a closed impeller small enough to give the desired capacity would not pass solids of any size. In most cases, however, the closed or semi-enclosed impeller is to be preferred.

In the design of closed impellers for handling sewage, the water passages have been made wider than in water pumps, all sharp edges and turns have been carefully avoided, thus reducing the chance of clogging to a minimum. As a general rule pumps with impellers of this type will pass solids having diameters about one pipe size smaller than the size of the pump. One manufacturer is producing a pump with a worm feed to force the solids to the impeller of the pump and also cut and crush them against hard steel bars running longitudinally of the screw case. Pumps of this type are giving satisfactory service in several western stations. A rather unique impeller is used in some English pumps. The impeller is open on the suction side and the blades are considerably wider at the shaft than at their ends. The edges of the blades pass very close to bars set on the inside of the case and macerate the solids entering the pump.

It is customary to require the impellers of the pumps to be made of bronze but with ordinary sewage there seems to be no advantage in the use of bronze as compared with that of cast iron. A few pumps have been installed having cast iron impellers coated with enamel and they are said to be giving satisfactory results. The manufacturers claim a slightly higher efficiency for this impeller than can be obtained with the bare metal impeller.

Submerged Vertical Pumps

For the smaller installations probably the submerged vertical centrifugal pump is the most commonly used. The sump may be made of cast iron or steel or may be of concrete. The motor and pump are both supported on a removable iron cover so that the pump can be lifted out of the sump for cleaning and repairs. Enough head room must, of course, be provided to allow the suction to clear the top of the sump when the pump is lifted out. It is also desirable that the discharge be brought up through the same plate so that it may be easily disconnected. In unheated pump houses, however, it is sometimes impossible to do this without danger of the sewage in the discharge line freezing. Where short separate discharges can be used, freezing can be avoided by omitting the check valves and allowing the sewage in the discharge pipe to flow back into the sump after each discharge. If screens are to be omitted it is usually advisable to provide a pump not smaller than 3 inches in size. Such a pump will have a capacity of from 50 to 300 gallons per minute, depending upon design of the impeller and the speed of the motor.

Float Controls

Sewage pumps are usually automatic in operation and the arrangement of the float control deserves more attention than it generally receives. The float may be connected to the electric switch either by a push rod or by a chain running over pulleys with a counterweight to balance the float. Either method operates satisfactorily if properly arranged. Floats that hang unprotected in the sump are apt to be moved sideways by the motion of the sewage causing the chain or rod to bind, or the rod to bend, making the float inoperative. In some designs the rod has a guide at the bottom to prevent such motion, but if the rod sticks in the guide or leaves the guide its inaccessible location makes it very difficult to repair. The lever float, sometimes used, has generally proved very unsatisfactory for sewage because rags are apt to collect on the lever and prevent its operation. As in the case just mentioned it is generally very difficult to reach such a float to repair or adjust it. The best design is one in which the float is arranged in a tube to guide and protect it and a removable cover plate provided over the tube so that the float can be readily lifted out.

Pumps in Separate Dry Wells

For the larger pump stations, and even in the small stations when the conditions will permit, the installation of the pumps in a separate dry well makes the most satisfactory arrangement. This leaves the pumps and their appurtenances accessible for repairs and adjustment. The pumps may be either vertical or horizontal. The vertical pumps have the advantage of requiring a smaller pit and of keeping all electrical equipment above ground and free from danger of flooding, while on the other hand the horizontal pumps are easier to keep in adjustment and alignment. If the pit is deep, one or more guide bearings will probably be required on the shafts of vertical pumps as it is necessary to divide the shafts into lengths of not more than 8 or 10 feet to prevent vibration. I-beams are usually set across the pit to carry these bearings, but it is often difficult to set these beams so as to get a perfect alignment of the shaft. In order to avoid this difficulty, several manufacturers are building steel lattice frames extending from the motor to the pump. The pump and motor can then be aligned at the factory with very satisfactory results. In some cases the motor, shaft and pump have been attached to a heavy channel, aligned at the factory, and shipped as a unit.

With the pumps in a separate dry well it will usually be necessary to provide some means for removing seepage from the well. This may be done with a separate automatic sump pump, or, if a cheaper installation is desired, a small valved connection may be made from the suction of one of the main pumps to a sump and the sump emptied at intervals by closing the main suction valve and opening the connection to the sump.

Design of Suction Well

The shape of the bottom of the suction or wet well is of considerable importance. If it is left flat, solids will collect in the bottom and ferment giving rise to unsatisfactory conditions. The floor of the wet well should have a steep slope toward the pump suctions.

In some cases where the sewage is warm and contains considerable grease, trouble has been experienced due to the grease congealing on the walls of the well and then breaking loose in large pieces and entering the pumps and clogging them. The openings in the impellers of 4-inch horizontal sewage pumps have been stopped several times by this cause.

Bearings and Glands

There does not appear to be very much choice in regard to the type of bearings used, ball bearings and sleeve bearings seem to serve equally well provided they are properly oiled. Ball bearings are, however, usually provided to take the thrust or to carry the weight of the impeller of a vertical pump. The part of the shaft that passes through the stuffing box should be of bronze or covered with a bronze sleeve otherwise difficulty will be experienced in keeping the packing in condition. This stuffing box is usually provided with a water seal, although grease seals and special devices are sometimes used. In water pumps the water for the seal is usually taken from the volute of the pump. With sewage pumps, however, this is not advisable for the solids in the sewage are apt to clog the small passages and also because the grit in the sewage will reach the packing and cut the pump shaft. To avoid the possibility of the pollution of the clear water with sewage, the water must usually be taken from a constant level tank supplied from the water lines and not directly from the lines themselves. With double suction and open impeller pumps, if there is a suction lift, there will probably be vacuum on the pump side of the stuffing box and the water seal serves to prevent the entrance of air. With end suction pumps, with enclosed or semi-enclosed impellers, there may be a pressure on the pump side of the stuffing box. The water seal then serves to prevent the grit in the sewage from reaching the packing and cutting the shaft. The pressure on the water seal should of course be greater than the sewage pressure.

Centrifugal sewage pumps will operate satisfactorily if set as high as 15 feet or even a little more above the sewage level, but in such cases special priming devices must be provided for the ordinary method of priming, by filling the suction from the discharge line, cannot be used because it is inadvisable to attach a foot valve to the bottom of the suction. While special priming devices can be used, it is better, if possible, to locate the pumps below the level.

Efficiency and Head

The non-clogging centrifugal pumps will generally give over all efficiencies varying from 35 per cent for the smaller sizes to 65 per cent for the larger pumps. The lift of sewage pumps is usually low and most of the pumps are designed for heads under 40 feet but pumps can be obtained that will lift sewage against heads as high as 75 or even 100 feet. Beyond this head two stages are needed, but the ordinary type of multi-stage pump used for water cannot be used because of the many sharp turns and the narrowness of the water passages. At a station where it was necessary to raise sewage 180 feet, two pumps connected in series on the same base, with the motor between them, have been used successfully. The overall efficiency of the unit was found on test to be 35 per cent.

Hydraulic Characteristics of Centrifugal Pumps

With centrifugal pumps, careful attention must be given to the hydraulic characteristics of the pumps in designing a pumping station, particularly if the discharge line is of any considerable length.

If an engineer desires a pump to deliver 300 gallons per minute against a head of 20 feet he is very apt to add a little to the head for safety and specify that the pump shall deliver 300 gallons a minute against a head of say 21 feet. A typical 4-inch pump will meet these specifications almost exactly, and will require about 2¼ horsepower to operate it and, a 3-horsepower motor will serve satisfactorily. If, after installation, it is found that the actual head is only 18 feet instead of 21 feet, due to some unforeseen condition or due to the fact that the engineer figured his friction for 10 year old pipe and the pipe is actually new pipe, this pump will deliver 600 gallons per minute instead of 300 gallons per minute and will require 3½ horsepower. The 3-horsepower motor will in that case be overloaded. Conditions similar to this occur very frequently and it is best in all cases to require the motor to be of sufficient size to operate the pump without overheating at any head between the maximum and zero.

When two or more pumps are connected to the same discharge line, the reverse condition often occurs. If two pumps, having the characteristics mentioned above, are connected to a single discharge line, one pump operating alone will discharge 300 gallons per minute. When both pumps are put in operation the friction loss in the discharge line will of course increase. With the particular 4-inch pump just mentioned, if this increase is only about 1½ feet (from 21.0 feet to 22.6 feet) the discharge of each pump will be reduced to 200 gallons a minute or the total discharge of the two pumps will be about 400 gallons per minute or only slightly greater than the discharge of one pump. For this reason it is often found desirable, especially with long discharge lines, to arrange the controls so that one pump will shut off entirely and the second pump, designed for a larger capacity and a little higher head, will start when the sewage flow exceeds the capacity of the first pump.

Multispeed motors are sometimes used to meet these conditions but such motors operate only at certain fixed speeds and it is generally difficult to design the pumps to obtain the desired capacities at these motor speeds. Any desired speed may be obtained by using variable speed motors, but if this is done the losses in the resistances greatly reduce the overall efficiency of the pumping equipment.

At the Harlem Valley State Hospital pumping station which contains 8 4-inch 450 gallon per minute pumps, a special arrangement was used. As each additional pump starts the friction loss in the discharge line increases approximately 6 inches. The controlling float and float switches are so arranged that as each additional pump starts the sewage level in the suction well is automatically allowed to rise 6 inches. Thereby, the total head, and consequently the discharge of each pump, always remains the same and has proved a distinct advantage.

Suction Line Difficulties

There are several matters in connection with the arrangement of centrifugal pump suction lines, particularly where there is some suction lift, which, while they seem very simple, have caused engineers and operators considerable trouble. There must be no high point in any suction line where air or sewage gases may accumulate. When the pump is started the accumulated air will expand, flow to the pump, and stop its operation. The reducer at the pump must for this reason always be an eccentric reducer with the flat side up. Connections to a

common suction header must for the same reason be made at the top of the header and not at the center of the side. In some extreme cases it has even been found necessary to place the suction valves horizontally so as to avoid the accumulation of air in the bonnets. Common suctions, that is, single suction lines to which two or more pumps are connected, are a source of trouble in many cases where there is a suction lift, and wherever possible should be avoided. It is often difficult in such cases to make each pump take its share of the load. When one pump is in operation it is often impossible to start the second without shutting down the first and starting both together. A slight leak in the stuffing box of one of the idle pumps will many times admit enough air to interfere with the operation of the other pumps. Even when the pump that is not to be operated is entirely shut off, air will frequently accumulate in the riser from the common suction to that pump and will expand when the other pump or pumps are started and enter them and prevent them from operating.

Part II—Sludge Pumping

Pumps designed for moving or lifting sewage sludge may, in general, be divided into two distinct classes, displacement pumps and centrifugal pumps. Since these two classes differ radically in their design and operation and present entirely different problems for those in charge of them, it is necessary to consider them separately. The advantages and disadvantages of each class are matters which engineers and operators are not entirely agreed upon. Displacement pumps are unquestionably more easily primed than centrifugal pumps when there is a suction lift and will probably handle small quantities of sludge more readily than centrifugal pumps, but beyond this it is doubtful whether the advocates of either class will admit the superiority of the other.

Displacement Pumps

The modern displacement pumps used for handling sludge are always of the single acting reciprocating type, and are usually electric motor driven plunger pumps having one, two or more cylinders. The makes most commonly used generally have cylinders about ten inches in diameter and strokes adjustable from about two to five inches. The pumps are connected to the motors by gears, belts or chains and the motion transmitted to the pistons by walking beams or eccentrics. Each manufacturer apparently believes that the transmission used by him is the best, but in practice there seems to be little difference.

Transmission

Certain matters in connection with the transmission are, however, of importance. If it is desired to have the pump run smoothly it is usually best to keep the speed of the main pump shaft below about thirty-five revolutions per minute. This gives a piston speed of thirty feet a minute or less, a low figure as compared with the usual figures for water pumps; but the strokes of these sludge pumps are very short and the frequency of the reversals seem to be of more importance than the actual piston speed. Pumps of this type are generally arranged so that the length of the stroke can be changed by shifting an eccentric or, which amounts to the same thing, altering the length of the crank arm. This makes it possible to obtain several different rates of discharge, but experience indicates that the use of the shorter strokes is not always entirely satisfactory. The pumps in most cases do not operate as smoothly with the short strokes as with longer ones, the slip is greater and the efficiency lower. The use of multi-speed motors and variable speed transmissions, although more expensive, afford a more satisfactory and efficient method of changing the pump capacities to suit the conditions, and where available should be used in preference to changing the length of the stroke.

Packing

Like all reciprocating pumps the sludge pumps must be packed to prevent leakage between the pistons and the cylinders, and this packing is one of the most frequent causes of trouble in the operation of the pumps. The packing may be either on the cylinder or the piston. Generally it consists of from 4 to 6 rings of ½ inch to ¾ inch packing held in place by an adjustable metal ring or gland. If the packing is too tight, scored pistons or cylinders and broken shear pins will be the result. If the packing is too soft, too loose or improperly placed it will leak, and since the pumps are outside packed this means that the pumps and probably the floor around them will soon be covered with sludge which does not add to the attractiveness of any sewage treatment plant. Opinions differ as to the most satisfactory type of packing. Generally a square braided flax packing serves as well as any. A graphited packing may be desirable to prevent unsatisfactory conditions due to rust where the pumps stand idle for a considerable time. Rawhide packing is satisfactory but does not seem to be necessary except with certain chemicals. The packing must fit and must be properly placed. In cutting the packing it is well to use a template into which a piece of packing exactly the length of one ring can be fitted. In this way each ring will have the same length and the same bevel. The method of oiling the packing varies with the make of the pump. Generally it is found that a fairly heavy oil such as a good grade of cylinder oil gives the best results. Oils known as "500 W" and "Marine Pump Oil" are in common use. A light oil disappears very rapidly. Under continuous operation the packing will usually last about 3 months, but under intermittent operation it may last a year or two. Manufacturers have recently been giving more attention to the finishing of the pistons and cylinders, in some cases grinding them. This has made it easier for operators to keep sludge from leaking between the pistons and cylinders but has not done away with the necessity for careful packing.

Valves

Each cylinder of a reciprocating pump necessarily has an inlet valve and a discharge valve. These valves may be weighted flap valves or ball valves. Each type has its advocates although at present the ball valves seem to be preferred by most operators. Spring loaded poppet valves which operate satisfactorily in water pumps obviously cannot be used for liquids containing an appreciable amount of solids. No mater which type is used the valves will require some attention from the operator. With raw sludge the valves may require cleaning from two to three times a day to two or three times a week. If the pump is handling activated or secondary tank sludge, cleaning will of course be required less frequently. Fibrous material will collect under the hinges or flap valves and rags will accumulate under ball valves holding the valves off their seats and rendering the pump inoperative. Metal flap valves wear at the hinges so that the flap will not seat properly and soon require replacement. Valves of rubber with rubber hinges clog less frequently than metal valves because of their smoother surfaces, but the rubber hinges are inclined to swell and split and it is difficult to turn them back for cleaning. Ball valves are usually of rubber moulded on an iron core. If they are to operate satisfactorily, careful attention must be given to the quality of the rubber, the balance of the valve and the weight of the core. Valves made of a poor quality of rubber will sometimes swell and stick, and cases are on record where the rubber has softened so as to allow the ball to be forced into the piping stopping the pump. The valve must balance or the ball will always seat at the same point and wear rapidly. The weight of the valve must be suitable for the conditions under which it will operate.

Pounding or Knocking

One of the most frequent complaints heard regarding the operation of reciprocating pumps is that they knock or pound. This is due to various causes. Since sludge lines are usually comparatively short, the high water hammer stresses sometimes encountered at water pumping stations are seldom of importance, but the flow of liquid in the suction and discharge lines must be stopped and started with each stroke (single cylinder pump with no air chamber), the valves must close and in doing so strike the seat, and each stroke causes a reversal of stresses in the piston, the crank and the connecting mechanism. These conditions cause pounding which cannot in all cases be entirely eliminated. The subject is too complicated to be discussed in detail here.

The stresses and pounding due to starting and stopping the flow in the discharge line can be generally alleviated by the use of an air chamber, but the air chamber must be large to be of any value. The same thing is true of the suction line, although an air chamber is not so frequently used at this point. One manufacturer provides a small air inlet valve on the suction of the pump which if properly adjusted seems to make the pump operate more smoothly, but of course somewhat reduces its capacity and efficiency.

Valve slam is sometimes due to the fact that the direction of flow through the valve reverses and acquires considerable ve-

locity before the valve closes. This velocity may then carry the valve to its seat rapidly enough to cause a heavy blow when the motion of the valve and the liquid is suddenly stopped. This reverse flow of water through the valve is of course slippage and reduces the efficiency of the pump as well as causing valve slam. The valve should, for these reasons, be heavy enough and so arranged as to close as quickly as possible, and yet not interfere with the operation of the pumper by reducing the area of the ports.

The knocks due to the reversal of stresses in the different parts of a pump are the same as those which occur in any reciprocating machine. If there is any lost motion in a main bearing, eccentric, wrist pin or other part there will be a knock each time the stresses are reversed. The remedy is obvious. All bearings must be properly adjusted and kept properly lubricated.

Centrifugal Pumps

Centrifugal pumps, if they are to handle sludge successfully, must pass solids without frequent clogging. This makes it necessary to use end suction pumps at least 4 inches in size with as few bends and sharp corners in the liquid passages as possible. The impellers usually have only two blades with long sweeping curves and are either fully enclosed or have a shroud on one side. Open impellers clog very rapidly when the liquid contains rags. Even with these precautions, it is generally desirable to have hand holes or other means of access to the interoir.

One pump manufacturing company equips its centrifugal sludge pumps with a screw to force the sludge into the pump and to macerate the solids as they enter. Pumps of this type have been in operation at a number of plants for several years. Similar devices are being made by some other manufacturers but have not as yet come into extensive use.

Capacity and Regulation

A 4-inch centrifugal pump will readily discharge 100 gallons a minute and in some cases as low as 50 gallons a minute, but if capacities below this are necessary some difficulty is apt to be experienced unless provision is made for reducing the speed below that which can be obtained by a direct connected motor. Variations in head, of course, cause variations in the capacity of a centrifugal pump and if a definite quantity of discharge is required some method must be provided to compensate for these variations. In many plants it is necessary to change the quantity of sludge delivered from time to time and provision must be made for so doing. Theoretically, throttling might accomplish these ends, but throttling is not desirable when pumping sludge. If careful adjustment of the quantity of sludge delivered is necessary the only practical method of regulations seem to be to change the speed of the pump. Variable and multi-speed motors will do this within limits but are not as satisfactory as some of the variable speed transmissions available. These transmissions, while expensive, make it possible to obtain almost any capacity within the limits of the pumps. It must not be forgotten, however, that a centrifugal pump will give its highest efficiency at one definite speed and capacity and that as the speed and capacity are changed the efficiency may fall off rapidly. This is naturally of more importance when the pumps are in continuous operation than when they are operated intermittently.

Priming and Seals

Centrifugal pumps will not handle air and when they are used careful consideration must always be given to priming and to the elimination of air pockets in the suction line. To facilitate priming, centrifugal pumps should if possible be set below the surface of the liquid in the suction well. If the pump must be set above the level of the liquid some means of priming must be provided. Foot valves which are often used with water pumps will not serve satisfactorily with pumps handling sludge. Vacuum systems are available and operate satisfactorily if kept in condition, but mean added expense of installation and more equipment for the operator to maintain.

The impeller shaft of every pump of this kind must pass through the pump casing and therefore requires a stuffing box to prevent leakage. On water pumps these stuffing boxes are provided with water seals and the water taken from the pumps. The material handled by a sludge pump is not, however, suitable for the seals and water must be obtained from some source. A direct connection to the water system cannot be used due to the danger of polluting the water supply with sludge. If the building is high enough a small tank fed over the top and controlled by a float valve may be used as a source of water. The height of the tank must be greater than the discharge head of pump or the sludge will be forced into the packing and probably result in the scoring of the shaft. If the tank cannot be set high enough, a small pump may be used to supply water to the seal. Grease seals and other special devices are sometimes used but are not as satisfactory as water seals.

PACKING POINTERS

The following suggestions and warnings, based on the many years of practical experience of a prominent eastern packing manufacturer, will be found valuable in the installation of packings. To follow them may mean freedom from trouble that would occur when even the best packing is improperly installed.

1. NEVER fail to make clear to the manufacturer what the packing is to pack. In other words, with what will the packing make contact?
2. NEVER guess at a size, diameter, width, or height, when ordering packing. Many failures result from small errors in dimensions.
3. NEVER allow too little or too much clearance between follower plate and inside cup wall, or any metal parts behind any upright leather wall. Clearances of 1/16" to 3/32" on each side, depending on size of packing, is recommended.
4. NEVER doctor packing lips with a pocket knife or file, or batter lip in installing. A rounded lip destroys the seal. Packings can be softened by soaking in warm water if necessary.
5. NEVER apply cup packings with flange too high for clearance at the head of the cylinder. Keep systems clean, so sediment will not collect in cylinders and wear the packing.
6. NEVER apply cup packings to end of badly worn plungers; pressure will force the packing down into clearance between plunger and cylinder. Leather washers cut from old cup packings can be made to reline such equipment to proper dimensions.
7. NEVER apply "U" packings where plungers are worn without reinforcing under the heel with leather cushion rings.
8. NEVER look for long service on scored plungers or in scored cylinders; resurface or reline such equipment to proper dimensions.
9. NEVER allow water to corrode cylinder walls, plungers, stems or rods. Use an anti-rust agent that will prevent this and will act as a lubricant.
10. NEVER squeeze hemp or fabric filled "U" packings in glands where such packings are to replace solid section compression packings; set gland up to point where "U" packings are free to function properly.

The above suggestions were contributed by W. F. Schaphorst, M.E., Newark, N. J.

MAINTENANCE OF SEWAGE PUMPING STATIONS

By A. L. SODEN
Chief Operator
Sewage Treatment Works, Trenton, N. J.

THE writer, after some fifteen years of experience with seven pumping stations containing twenty-seven pumps with capacities from 50,000 to 11,000,000 gallons per day, has come to the very definite conclusion that maintenance of this type of equipment involves three main objectives, proper lubrication, cleanliness, and frequent detailed inspection. At first thought the first two involve the last, but dumping oil or grease into a machine plus wiping it off do not constitute inspection any more than feeding and bathing a baby is a substitute for a doctor's periodic checkup. The point I wish to drive home is that good maintenance catches trouble *before it starts* and postpones indefinitely the day when the machine must be scrapped for any other reason than obsolescence.

The use of good oil and grease is a very essential item. Lubricants not suited for each particular piece of equipment may, however, no matter what they cost, do more damage than a cheap oil of a suitable character. It must be kept in mind that too much oil in many cases tends to cause more wear than too little, due to the fact that dust, always present in the air, will mix with the oil and act as an abrasive when passing through the bearings. This situation is more serious in a gravity or pressure feed system than with the oil reservoir type.

It is axiomatic that efficient lubrication is a matter of using good lubricants, properly selected, in the correct quantity, at the right intervals. Neglect or omission of any of these factors means accelerated depreciation and breakdown.

Low Price—High Cost Lubricants

Cheap lubricants are costly in the long run and if the average operator would only sit down and figure the total saving per year in a few cents less per quart of oil, or pound of grease, as against many dollars for new bearings, sleeves and shafting, damaged by cheap "bargain" goods he would realize that the best is none too good. We had an example of this in Trenton where for a time the purchasing department paid twenty-seven cents per gallon for automobile oil which was bought on a price basis.

Even though good materials are supplied, one must be certain that they are of the right weight, viscosity, etc., for the job and the only way to be certain is to follow the manufacturer's recommendation for the unit being serviced, or, if this is not available, call in a lubrication engineer from one of the big companies. You will note the word "engineer"—beware of smooth talking salesmen with trick oils that never wear out, made by some magical process and sold at high prices under a fancy name.

It may seem proper to the average person that as long as the correct amount of oil or grease is in a bearing and no noise or heat is noticeable that the machine could run indefinitely. This, however, is *not* true as many pieces of equipment are installed in damp wells where condensation is present, the worst enemy of any bearing no matter what type lubrication is used.

Gravity or pressure feed lubrication systems with an oil filter in the line do not require as much attention as equipment having the oil reservoir. A good method to follow is draining and flushing these types of bearings and refilling with new oil at least every six months, and in some instances where water is present, every three months.

Shaft Bearings

Many line shaft bearings are made for grease lubrication and can be run with safety on equipment in small booster stations for about a year before flushing and repacking with new grease. We have found through past experience that it is sound economy to remove the bearings from the shafts and wash thoroughly in gasoline or kerosene, both the bearings and the oil reservoirs, thus removing all traces of moisture, old grease and foreign matter at least once a year. This procedure should be more frequent in a plant where the equipment is running continuously. Care should be taken to put the right amount of grease in a bearing as too much causes bearings to heat through increased friction.

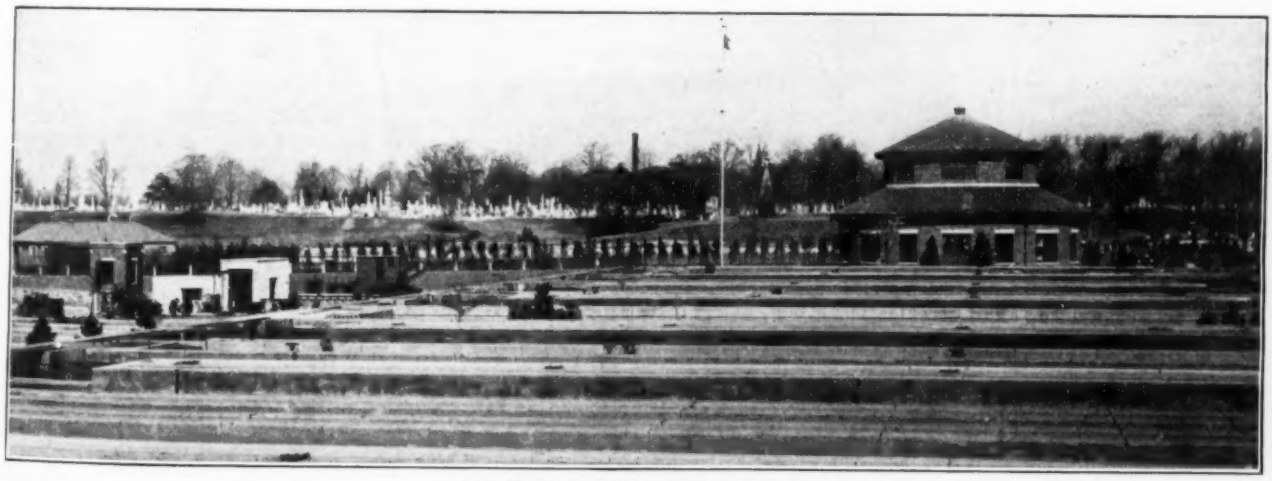
An oil filter, if used, should have at least twice the capacity of the lubricating system. This unit is used to separate the water and oil in a primary chamber and, in a secondary compartment, dirt in the oil which has a tendency to collect in bearing boxes, and any scaling which may develop in the oil lines. Such is particularly true if the latter are constructed of iron or steel pipe and fittings. Copper tubing or brass pipe and fittings are the only materials which should be used, thus preventing damage to bearings due to the stoppage of the oil grooves by pieces of rust or scale which come from iron or steel pipe, even though these be galvanized.

The matter of cleanliness around any machinery is a very important factor not only for looks but for the good of the equipment. It must be kept in mind that next to water, dust and dirt are the most destructive enemies to motors, bearings, controllers, starting switches, and many other pieces of electrical equipment that are found in a pumping station.

Motor Care

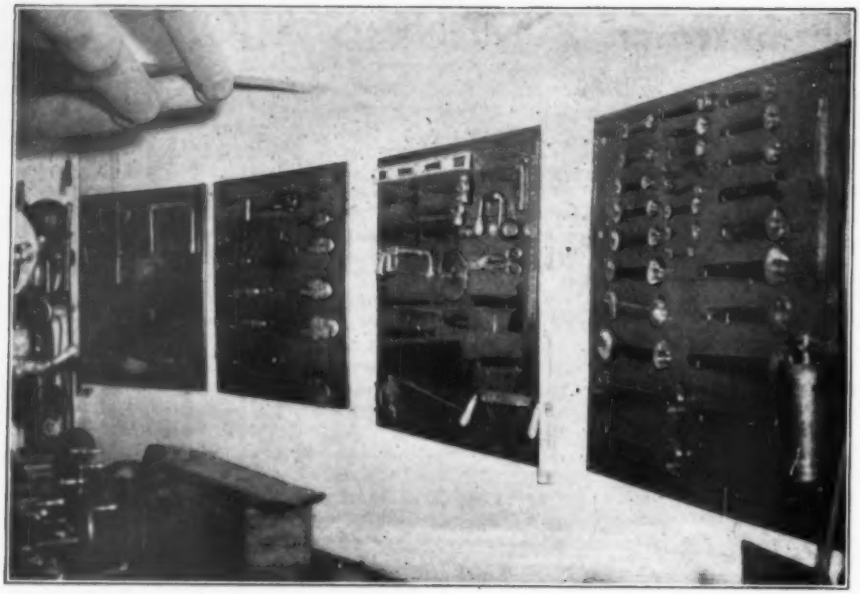
Motors must be kept free from water, oil and dirt. A good method of cleaning the interior is with compressed air or a bellows. When using compressed air care must be taken to be certain there is no moisture in the storage tank that could escape through the nozzle used for cleaning. Cleaning motors with compressed air should never be done by an amateur. The older the motor the more brittle the insulation and high pressure air through too small a nozzle can be very destructive to the motor insulation.

An excellent plan is to give the motors a thorough cleaning once every six months and at least once every two years give the windings a coat of a good grade of insulating varnish. At this time the bearings should be thoroughly cleaned and refilled with new oil, or repacked with new grease.



The Treatment Works of Trenton

One Battery of Imhoff Tanks and Pumping Station



Shop and Tool Room of the Main Pumping Station—Trenton, N. J.

Contactors

Contactors often give an operator more or less trouble due to particles of dust becoming imbedded in the contact fingers. It is a good plan never to use any lubricant on the main contact tips which are mostly constructed of copper, as oil or grease has a tendency to shorten the life of these items. If they should become pitted or burned, which in many cases cannot be avoided, remove the contact tips and clean up with a smooth file or very fine sand paper. Care should be taken when attempting to clean contacts in place not to bend or misalign the parts.

If the operating force is large enough it is a good policy to assign different parts of the equipment and pumping station to the shift operator or oilers and set up a system whereby the entire equipment and pumping station is cleaned at least once every month from top to bottom, besides the daily routine sweeping, mopping and dusting.

Insurance in Cleanliness

This, however, does not mean that the equipment should be dismantled and reassembled but it is important to get the dust and dirt, which is on the surface, before it has a chance to penetrate to the vital parts of the machinery. It will not work a hardship on any member of the operating force to do a little cleaning now and then, no matter what the title of the job he holds. By doing this a man gets around and has a chance to inspect parts of the equipment which he otherwise would not give a second glance unless trouble should develop in that particular spot.

To be clean is to be free from dirt, odor and keep tidy. There is no reason why a pumping station should not be kept clean, no matter what type—water or sewage. A little attention to cleanliness will result in continued satisfactory operating results and enable the operator to get the most efficient results and best service out of the equipment for many years.

Thoroughness

Maintenance of any piece of equipment should be as thorough as a doctor's examination, not just the usual haphazard method of looking or just glancing in the direction of the machinery. A system of inspection should be drawn up and followed to the letter.

Commutators and Brushes

Detailed inspection of motors, shafting, electrical equipment, pumps and piping should be done by men qualified through years of experience for they know what to look for in each unit.

In the case of single phase motors, commutators become rough and burned through continuous operation, dust and oil accumulating being the chief cause. Commutators should be polished with sand paper on a flat block of wood so that the insulation between the segments will be cut back even with the copper. Under no circumstances use emery cloth or emery paper in this operation. A commutator hone with the correct radius is the most efficient tool to use for this purpose.

The brushes should move freely in the brush holders, with the proper spring tension as recommended by the manufacturer. If they do not move freely, a good contact with the commutator will not be made during the starting period. Both brushes and brush holders should be inspected periodically to see that the brushes have not worn down to a point where they are so short that the brush holder springs cannot press the brushes against the commutator, thus causing burning of the brushes and commutator through arcing.

Motor-cleaning

It is a good policy in the case of single phase motors, having a short-circuiting device, to overhaul once every year. Motors of this type are hard to clean if not dismantled and every part thoroughly washed. There should never be any trouble at this point except for an abnormal accumulation of dirt or frequent overloads in excess of the maximum capacity of the motor.

The normal running temperature of an electric motor is considered a few degrees above the room temperature and should never be allowed to exceed the general standard of forty degrees centigrade above surrounding atmosphere. Motors will carry a full load continuously with no cause for concern if the room is well ventilated. Overloads or undue friction in the bearings will cause the temperature to rise and should be investigated immediately to remedy the trouble.

Motors of different sizes have their own peculiar sound when running, so an operator after a time will become accustomed to this sound and should any noise not characteristic to the motor develop, he will immediately detect it and look for the trouble and remedy it before any damage has been done.

Shafting and Bearings

Shafting in any plant requires attention more often than other parts of the equipment, to insure the longest possible life of the shaft and the shaft bearings. Shaft alignment may be as true as it is humanly possible to make it, but it will not necessarily stay aligned. A bearing wearing due to friction may cause a slight whip in the shaft and be transmitted to the other shaft bearings, thereby causing added play from vibration. A periodic check of the shaft alignment is most advisable.

Bearings on any shafting should be painted a light color, so when a bearing gathers too much heat the paint will discolor and can be detected immediately Many plants have a thermal overload device which stops the unit when too much heat develops in any shaft bearing. The operator must go to the bearing indicaated on the panel and reset the overload switch before the machine can be started again.

In plants which do not have such a device to depend on an operator must go to each bearing and rely on his sense of feeling, even this method will not tell the true story. A thermometer should be used in any and all cases where there is a suspicion of too much heat. Generally after a bearing has carried excessive heat it is too late even for a thermometer, instead a new bearing is indicated, this being true where periodic inspection is deficient.

When a shaft bearing becomes worn, no matter how little it is false economy to leave it in service. Worn shafting will vibrate and promote undue wear on both motor and pump bearings where direct connected. A bearing in this instance would be cheaper to replace than try to get by with, as possibly a whole section of shaft or motor and pump bearings will be ruined in a short time.

In stations that are automatically controlled by float or pressure switches and no attendant is on duty any length of time, it is advisable to paint the shafting to protect it against rusting. No metal will gather rust more quickly than a highly polished piece of steel. By doing this the unit can be wiped off and be kept clean.

Polished shafting should never be cleaned while the machine is in operation. Although a much better job can be done it is a very dangerous practice. Use of emery cloth should be avoided as the residue may enter the shaft bearing boxes and cause trouble. A good cleaning with soap and water and polishing with metal cleaner will give the best results and not endanger the man doing the cleaning.

It is very important to have uninterrupted operation in many

plants, where no standby units are installed. In case of power failure sufficient emergency lights should be available and special jumpers made up for continuous operation in case of burned out starters, float switches, etc.

Emergency Wiring

Rubber covered elevator cable is the most desirable material for emergency wiring, using copper lugs at either end of each wire. This will simplify connecting to the motor and main or branch switches, thereby removing from service the broken starter or float switch. Manual control will be necessary in the case where the float switch is not working. The size of the wire used for jumpers depends upon the size of the motor. This, however can only be applied to small low voltage motors of the "across the line" type. In case of large motors such as 50 HP, 2,300 volt, consult an electrical engineer for advice.

Pump Care

Necessary tools and equipment should be on hand in case of pump failure due to clogged impellers or any overload which would cause fuses to burn out or overload switches to kick out. Any pump being overloaded can be detected by the sudden rise of the ammeter.

Wearing rings in the pump case and on the impeller should be checked occasionally for clearance by using a thickness gauge. Install new rings when the gap has become large enough to impair the efficiency of the pump. New rings installed will improve the pumping capacity, thereby effecting a saving in the electric power consumption.

Packing Pointers

A most important factor, one which can cause much annoyance to the operator and plenty of damage to a pump is the proper size and grade of packing. For pumps handling dirty water—sand and grit—a packing should be selected with some thirty-five per cent lubrication, thus saving the sleeves from being worn too quickly and excessive seepage at the stuffing boxes. No gland should ever be pulled down with a wrench except at such times as to effect the proper seating when new packing is installed. Stuffing box gland nuts should never be more than finger tight, as too tight a packing will cause a braking effect on the pump shaft thereby overloading the motor.

Care should be taken when repacking any piece of machinery to see that the strands do not twist while being forced to the bottom of the stuffing box. Never under any circumstance use more packing in a stuffing box than is absolutely necessary to keep the pump from leaking at this point.

Consult a packing engineer if in doubt as to what grade of packing the unit may require. Experimenting with packing in a pump sometimes is very costly.

The piping in most instances will require little or no attention other than caulking a few leaks that may develop, or removing clogging material which can readily be detected by the use of an ordinary steam pressure gauge. A sudden rise of the gauge when connected to the force main will indicate clogging. It is of course necessary to know the normal reading for comparison.

Check Valves

Check valves should be inspected at least once every six months, including internal parts. At this time the seats, clapper faces, and whole interior can be thoroughly cleaned. At more frequent intervals test valves for tightness. Manila paper should be used for the cover gasket after being well oiled with machine oil before installing.

The building housing the equipment must be maintained as well as the machinery. The roof must be kept in constant repair so there is no possibility of water leaking through on the electrical apparatus thereby causing untold damage. Floors should be painted and rubber matting placed thereon at points in front and rear of the switchboard to protect the operator and on the floor where traffic is the heaviest, for appearance. Walls in the dry well should be inspected and repaired when necessary to prevent any seepage of sewage or ground water.

All wood work in the entire building should be painted or varnished at least every two years to protect against dampness, also to keep the appearance of the station up to par. Costly repairs may be caused by neglecting any part of the building.

Tools

It must be understood that no person can do repair work without the proper tools. A suggested list of tools to be included along with those supplied by the pump manufacturer are:

Tool List

Socket Wrench Set (sizes 7/16" to 1⅛" inclusive).
Pliers—2 pair (1—slip joint; 1—side cutting).
Screw Drivers—set of 3 (3, 4 and 6 in. blades).
Stillson Wrenches—two (one 10" and one 18").
Hammer (machinist's, 2 pound).
Oil Cans—3 or 4 (spout oilers, plainly marked as to contents).
Putty Knife (for scraping old gaskets from pump casings).
Thickness Gauge (for spacing and setting couplings and checking clearances of pump rings).
Packing Tools—full set for removing and replacing packings in stuffing boxes).
Assorted Packings (of pump mfgr's recommendation).
Spirit Level (machinist's level of dependable make).
Fuse Puller.
Voltage Tester.

Too many so-called mechanics of the Stillson wrench type do more damage to machinery attempting an overhaul job than several years of wear and tear, to which the machine is subject. A plant of any size should have among the personnel, men capable of doing all minor and most major repairs, thereby effecting a substantial saving in a year's time over hiring outside mechanics or specialty men to come in and make these repairs.

Spare Parts

Adequate spare parts should be kept on hand at all times to replace worn out or broken parts of the equipment, thus saving time. In many cases a unit may be out of service several days waiting for some part whose initial cost may be less than $5.00. Of course, it would be practically impossible to keep enough spare parts on hand to cover the entire equipment. However, essential parts: such as holding coils for contactors likely to burn out any time, and such parts that have to be made up special at the factory, taking 10 to 30 days for delivery, should be stocked.

A most important item in the operation of a plant is the budget. No matter how well the equipment is maintained, normal wear and depreciation must be taken care of. It is false economy to repair only one part of the machine and not replace all the worn parts, just to save a few dollars temporarily.

The old cry is heard many times about effecting economy by using drastic and scientific measures which look very good on paper but in general practice are not worth a second thought, compared to the cost that is likely to be involved by delaying necessary repairs.

Value of Record Keeping

Keeping records of plant operation is an important factor. Although at the time of recording the data compiled may not seem to be of any significance, it later can be used as a reference for comparing the upkeep, electrical energy required by the different units and depreciation. An excellent method to follow is the frequent reading at stated intervals of all instruments and gauges on the units that are operating, making notations from time to time of any adjustments together with the routine work as required of an operator while on duty. Daily tabulation of all charts and logs will readily tell the story of how the plant is operating—normally or otherwise. At the end of each month the daily tabulations can be set up in the form of a monthly report, showing for example, amount of rainfall, daily pumping average, daily maximum and minimum flow, amount of screenings and grit removed, and amount of sludge removed from different tanks.

The above data can easily be transformed into a yearly report going into more detail if necessary to show the cost of pumping and treating the sewage.

In conclusion, an operator without the aid of expensive testing instruments can readily operate a plant by using some degree of intelligence and the better known common sense. His natal equipment of eyes, ears, nose and sense of touch are all invaluable aids provided, of course, that his head is something better than a hatrack.

CHICAGO PUMP COMPANY

2349 Wolfram St., CHICAGO, ILLINOIS

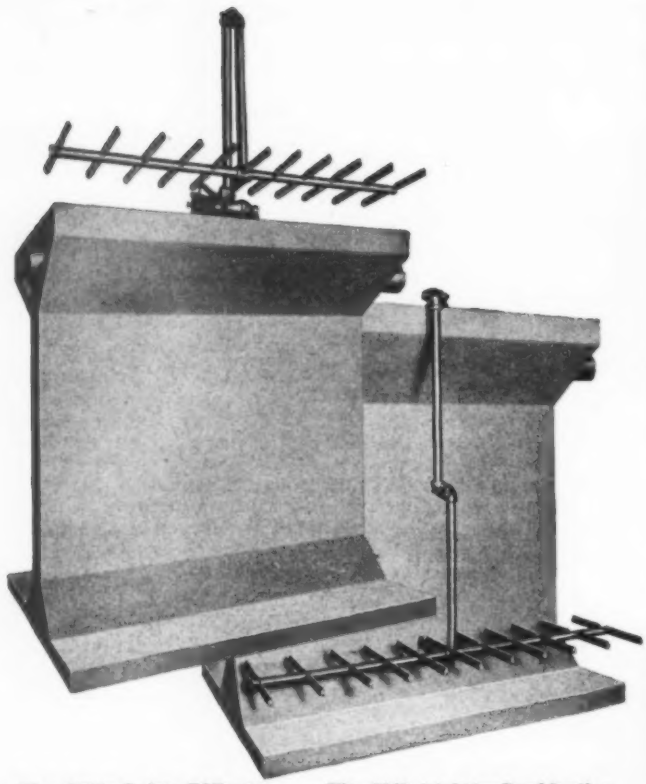


Fig. 2914—Swing Diffusers
Controlled aeration for the Activated Sludge Process. For towns of 4,000 and up. Diffuser tube assembly can be raised to tank walk. Simple regulation of air supply from tank walk. Tube cleaning without dewatering tanks or interrupting operation. Ask for Bulletin 175.

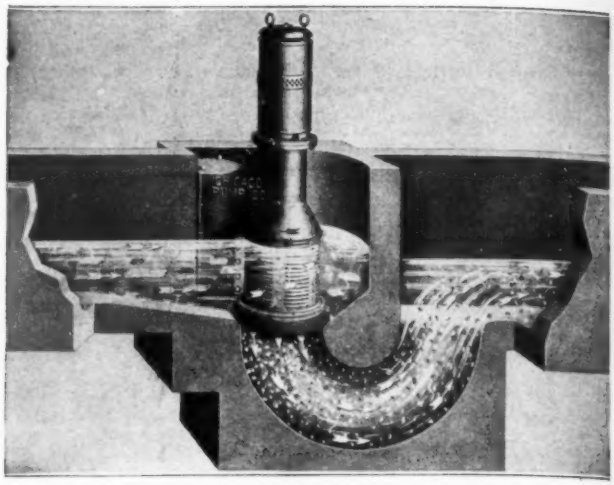


Fig. 2202—Comminutor
Eliminates screenings and screenings disposal—No burial; No incineration. Cuts coarse sewage matter into small settleable solids without removal from the channel.

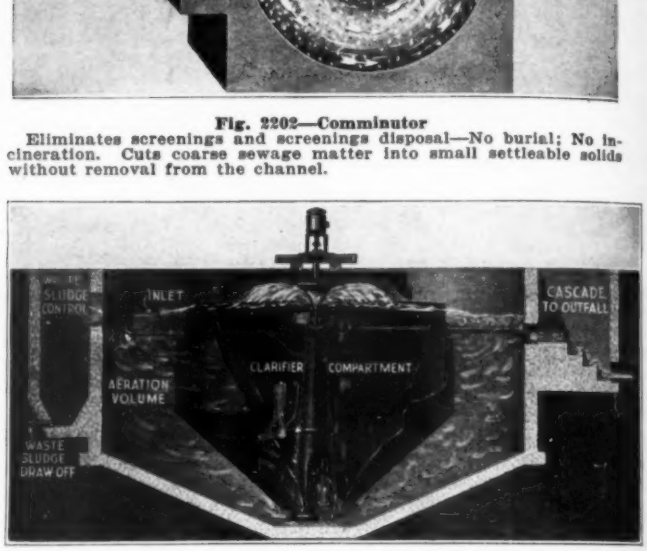


Fig. 2349 (right)**—Combination Aerator-Clarifier**
providing complete treatment of sewage without odor nuisance and with minimum manual operation. Ideal for housing projects, small camps, institutions and small towns. Over 75 units operating successfully. Ask for Bulletin 128-K.

Fig 2504—Vertical Open-Shaft Non-Clog Pump
Universal Flexible Couplings in shaft compensate for misalignment. Ask for Bulletin 126.

Fig. 1860—Scru-Feller Primary Sludge Pump
Screw conveyor in the suction ahead of the impeller. Stellited cutters prevent clogging. The capacity can be varied instantly. Ask for Bulletin 190.

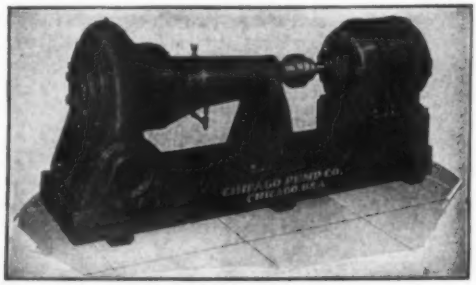


Fig. 1774—Horizontal Non-Clog Pump
Being mounted directly on base prevents pump being pulled out of alignment by long lines of piping. Ask for Bulletin 127.

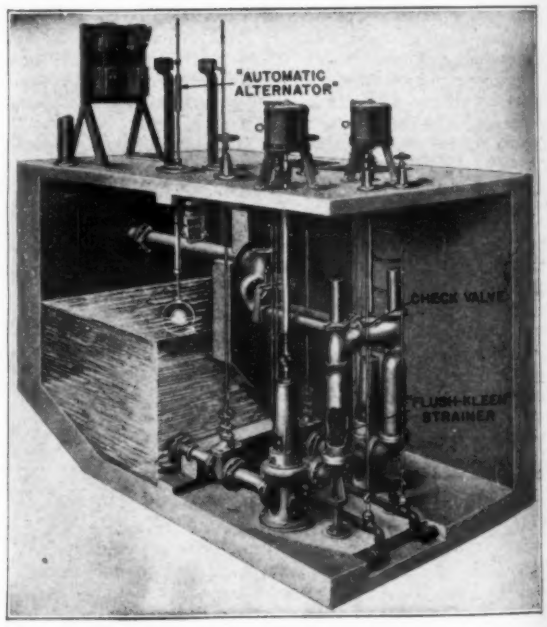


Fig. 2038—Flush-Kleen Sewage Pumping Station
Requires no attention. NEVER CLOGS. Automatically backwashes strainer. Keeps solids from basin and pumps. Impeller handles water only. Coarse sewage matter is stopped by Flush-Kleen strainer and is flushed out through discharge pipe. Check valve prevents discharging back through inlet line. Ask for Bulletin 122.

SLUDGE PUMPING

A Discussion on Pumps, Installation, Design and Operating Problems

By S. E. KAPPE, Engineer
Chicago Pump Co., Washington, D. C.

THE purpose of this paper is to discuss briefly the problems encountered in moving sewage sludges from one tank to another. The paper covers the type of pumps used for sludge pumping, their respective advantages and disadvantages, the design of sludge lines, and the problems involved in sludge pumping and their solution. Since the writer's firm manufactures all types of pumps commonly used for sludge pumping, an opportunity is presented to discuss the subject from experience gathered in actual plant operation.

The Plunger Pump

The plunger pump is popular because of its positive displacement characteristics. It will pump mixtures of sludges, sewage gases, and air equally as well as liquids. It is this self-priming feature which makes the pump more readily primed than a centrifugal pump where a suction lift is involved, or high spots exist in the suction line where gases may accumulate. Beyond this characteristic, however, it is questionable whether this pump offers any other superiority over other well-designed sludge pumps.

The following are some of the objectionable features of the plunger pump. The pump is often very noisy, complaint being frequent that it pounds and knocks. Such pounding is due to the reversal stresses in the different parts of the pump, caused by the starting and stopping of the column of heavy fluid on the suction and discharge side at each stroke. This noise can often be minimized by providing adequate air chambers on both the suction and discharge sides, and by reducing the pump speed. The reverse flow of the sludge through the valves is commonly known as slippage. It reduces the delivery of the pump, and, as a consequence, its efficiency.

Another objectionable feature is the maintenance required to keep the packing tight. If the packing is too soft, too loose, or improperly placed, the operator might find himself as well as the walls and floor sprayed with sludge, leaving an unpleasant taste and a messy cleaning job. Then if the packing is *too* tight, scored pistons or cylinders and broken shear pins may be experienced. The amount of grit in the sludge will govern the life of the packing and, likewise, the wear to which the pistons and cylinders will be subject. An effective grit chamber at the head of the treatment plant is an asset in prolonging the life of sludge pumps, and plunger type pumps in particular.

The valves on the suction and discharge side, whether they be ball or flap type, often require frequent attention. Clogging material will accumulate under the valve seats and around the valves and may cause the pump to stop delivering completely. The valves should, therefore, be inspected periodically. Poor valves may swell and stick, or the rubber may soften or become worn down by gritty material to a size that can be forced into the pump or piping.

The Centrifugal Pump

Centrifugal sludge pumps cannot, like the plunger pump, handle sludges containing large amounts of gas or air. If there is too much sludge gas and air present, the centrifugal pump becomes gas-bound. Therefore, it can readily be seen that this type of pump is not as adaptable for use where there is a suction lift or where air or gas pockets can exist in suction lines. It is also necessary to prevent air from being sucked in through the stuffing boxes. For this purpose waterseals must be provided. This does not mean that this type pump cannot be used for suction lift duty. On the contrary, there are many centrifugal sludge pumps operating successfully under suction lifts up to fifteen feet.

When suction lift duty is involved, a priming chamber should be provided. This priming chamber must perform the dual service of automatic priming and removing accumulated air and gases from the suction line. Where a suction lift exists, the discharge nozzle of a horizontal centrifugal pump should be on the top side of the volute, either parallel to the floor or in a vertical upright position. If the discharge nozzle faces downward, or is placed on the bottom of the volute parallel to the floor, the pump can not be readily primed because there is no way for the entrapped air and gas in the top of the casing to escape.

In may surprise some to hear that, in general, the so-called non-clog type centrifual pump has not proven very satisfactory for sludge pumping service. The smaller the capacity, the more clogging difficulties could be expected from the concentrated amounts of hair, rags, and stringy material in the sludge. Best results are obtained if the suction line is short. The whirling action induced on the suction side of this type pump is not conducive to trouble-free operation. The impeller motion causes the sludge in the suction pipe to rotate in a whirling or spiral motion for a distance of fifteen feet or more. This whirling action will often twist and enmesh the concentrated hair, rags, and stringy material in the sludge into ropes, or wads, which will then clog the impeller of so-called non-clog pumps. Another objection is that the centrifugal force at the suction eye of the impeller may partially dewater the sludge and thus cause clogging.

Centrifugal pumps perform best under positive suction head conditions. This type pump is preferred by many because its operation is quiet and clean, and there are no ball valves or flap valves incorporated which would need periodic attention.

Force-Feed Centrifugals

In spite of all the inherent weaknesses of the plunger pump, until the development of special force feeding centrifugal pumps, the plunger pump was the best available for pumping sludges, particularly in the small capacity ranges. Numerous attempts were made to design a sludge pump incorporating the good features of both the plunger pump and centrifugal pump. In this direction the best answer today is the sludge pump conceived by the late Walter A. Bell while Plant Superintendent of the Northside Treatment Plant, Chicago, Illinois. This sludge pump is a modification of the centrifugal pump and is known today as the "scru-peller" sludge pump. This pump, however, has the inherent priming weakness of the centrifugal pump. This objection is overcome by the use of proper priming equipment. It has all the advantages of the centrifugal pump plus the ability to pass solids better than any other pump without clogging. Although the pump was designed for handling sludges, it has been used successfully at Army posts since 1934 for pumping raw, unscreened sewages.

The "scru-peller" pump has a two-screw conveyor which gives positive feed to a two-port impeller, thus eliminating the danger of partial sludge dewatering at the suction eye of the impeller. Cutting devices are provided in the conveyor housing to cut rags and other material into sizes that will pass through the pump. Cutting devices are also provided on the back of the impeller to prevent packing at this point. The suction nozzle is at right angles to the conveyor to prevent a whirling motion in the suction line. Bearing supports are provided at each end of the pump, as in plunger pump design, to absorb the shock imposed by the cutting load. If only one bearing was provided, the cutting load and uneven sludge concentration would impose too severe a load and strain on the bearing and shaft. Likewise, a two-port impeller is provided instead of a single vane impeller, because it would be impossible to balance a single vane hydraulically. The changing consistency of the sludge would cause undue vibration and whipping of the shaft. The operation of this pump is quiet. It is clean, because packing troubles are corrected in the design features. Having no valves, it is free from clogging and other ball and flap valve troubles.

The Sludge Piping System

Now that we have covered the advantages and disadvantages of sludge pumps, let us consider the factors that a well-designed sludge pipe system should incorporate:

1—A positive suction head is more desirable than a suction lift, regardless of the type of sludge pump used. Positive suction heads will minimize the difficulty of moving heavy sludges at the beginning of the pumping period.

2—The suction line should be as short as possible. The pipe

line should be entirely horizontal or slope towards the pump or rise vertically and then horizontally into the pump. The suction line at the point entering the pump should never be lower than any other point on the suction line. (See sketch.)

3—The number of bends should be at a minimum. Elbows and tees should have long radius bends to minimize stoppage.

4—The suction inlet end should be located on the side of the sludge well to prevent formation of a vortex and, as a result, prevent flow of air into the suction line. A suction inlet in the bottom of the sludge hoppers is likely to be clogged by tools dropped into the hopper.

5—Foot valves, float valves and check valves should never be used on the suction side of the pump.

6—A combination vacuum and pressure gauge should be provided on the suction side, and a pressure gauge on the discharge side of the pump. These gauges will indicate if clogging troubles are on the suction or discharge side and will indicate a build up in pumping head that may be taking place due to sludge caking (sludge ring) in the pipe lines.

7—The check valves on the discharge side of the pump should be placed near the top of the vertical run or, preferably, in the horizontal section if possible. (See sketch.) The position of the valve should be such that when the pump is shut down undue amounts of grit and other foreign material in the sludge will not settle and pack on top of the flapper and prevent the check from opening when pumping is again started.

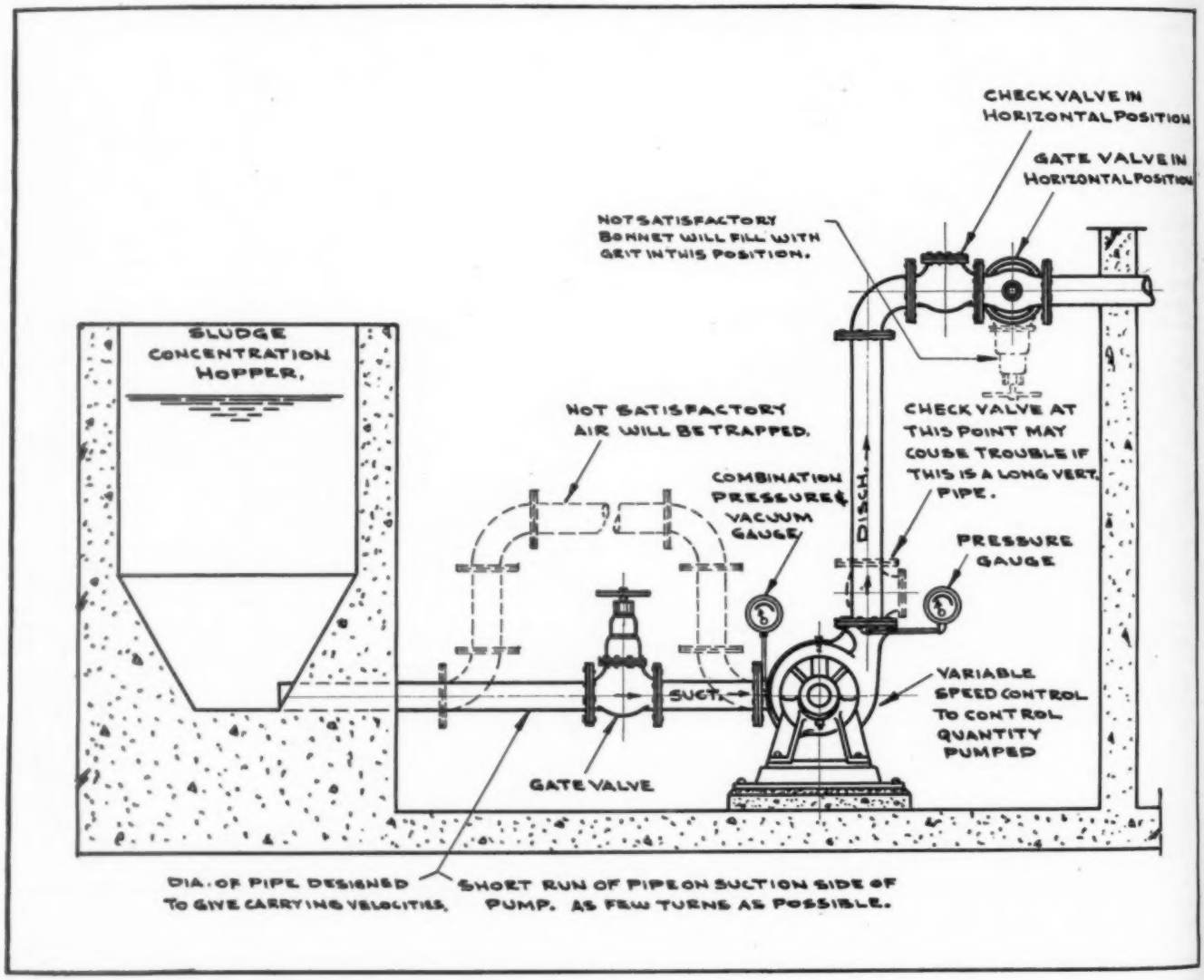
8—Pipe sizes on the suction and discharge side of the pump should be selected to assure scouring velocities (not less than 1 f.p.s.) in the sludge lines. Self-cleaning velocities will prevent or minimize sludge caking on the inside of the pipe. If the sludge line is too large to give cleansing velocities, the sludge will cake on the inside of the pipe line. In time this sludge cake will slough off and in all probabilities clog the line if not the pump.

It is difficult to understand why most of the sludge lines now in use, where the sludge is pumped, were not designed to fit the pump capacity and also give cleansing velocities. We would not think of designing a sewer with a velocity less than 2 f.p.s., even though the solids content is only 0.1 per cent. Yet sludge lines are built with velocities less than 0.5 f.p.s., handling concentrated solids as high as 6 per cent or more.

On a gravity system, or the sludge withdrawal system of Imhoff tanks, there is generally little trouble in the use of large sludge pipe lines, because normally the sludge lines are short and adequate head is available so that full opening of the gate valve will give high scouring velocities. But on a pumping system, the capacity of the pump and size of the sludge line will govern the velocity in the pipe.

In referring to the hydraulic tables it will be noted that in order to get a minimum velocity of 1 f.p.s., the approximate pump capacity for a 4-inch line should be 40 g.p.m.; for a 6-inch pipe, 90 g.p.m.; for an 8-inch pipe, 160 g.p.m.; and twice as much if a velocity of 2 f.p.s. is required. Slow velocities will also cause the heavier material to roll along the bottom of the pipe line. One can picture this rolling action enmeshing hair, rags and stringy material in the sludges and forming wads that may clog the pipe line or valves on the plunger pump.

Arguments generally presented are that 6 inch, 8 inch, and 10 inch sludge pipes must be used to pass the concentrated material and prevent clogging. The fallacy of this argument is that it


CHECK VALVE IN HORIZONTAL POSITION
GATE VALVE IN HORIZONTAL POSITION
NOT SATISFACTORY BONNET WILL FILL WITH GRIT IN THIS POSITION.
SLUDGE CONCENTRATION HOPPER.
NOT SATISFACTORY AIR WILL BE TRAPPED.
CHECK VALVE AT THIS POINT MAY COUSE TROUBLE IF THIS IS A LONG VERT. PIPE.
COMBINATION PRESSURE & VACUUM GAUGE
DISCH.
PRESSURE GAUGE
SUCT.
VARIABLE SPEED CONTROL TO CONTROL QUANTITY PUMPED
GATE VALVE
DIA. OF PIPE DESIGNED TO GIVE CARRYING VELOCITIES.
SHORT RUN OF PIPE ON SUCTION SIDE OF PUMP. AS FEW TURNS AS POSSIBLE.

Sketch Illustrating Some Good and Some Not-so-Good Features of Sludge Pump Installations
Installation of "Scru-peller" Sludge Pumps at Lebanon, Pa.

augments clogging troubles. If a plunger pump is used it is questionable if its ball valve chambers will pass a 1 inch sphere let alone a 5 inch or 6 inch sphere, and we know that match sticks will cause plunger pumps to lose their prime and cause a reduction in pump capacity due to slippage. If a "scru-peller pump" is used, whatever reaches the pump that is cuttable will be cut up and passed through the pump. Nevertheless, slow velocities cause sludge caking to build up on the inside of the pipe. In time this scum will break loose and plug the sludge lines usually at a bend, fitting, or valve.

Causes of Capacity Loss

Perhaps you have noted that the pump sometimes does not deliver its rated capacity. Let us analyze the reason for this condition: In the case of plunger pumps, the valves may have been worn to an extent that they cause too much slippage. Then again, sludges when subject to a suction lift or vacuum may release gasses to an extent that the pump may be pumping gobs of air followed by slugs of sludge.

We know that primary sludges have a varying degree of moisture. The moisture content in the sludge will generally be lowest at the beginning of the pumping cycle and will increase progressively to the end of the pumping cycle. During any cycle of pumping, the moisture content may vary from 90 per cent to 99 per cent. Sludges which have a moisture content of only 90 per cent will have a very high friction factor compared with sludges of 99 per cent moisture content. It is for this reason that during the first two or three minutes or more of any pumping cycle it is hard to get the sludge moving. The friction loss may be five to ten times greater than the friction loss during the balance of the pumping cycle.

It is generally easier to pump sludges having solids contents of less than 7 per cent. Above this point, depending on the character of the sludge, and particularly if it is around 10 per cent, you might have less trouble if you shovel it. Another point to remember is that sludges from one plant may be more difficult to pump than sludges from another plant, even though the solids content may be the same.

The unpredictable character of the sludge and its changing solids content has frustrated all attempts to establish accurate friction losses in sludge lines. As a result, it is more or less necessary to estimate the total dynamic pumping head. If you wish to increase or decrease the capacity of the pump, the simplest way is to equip the pump with a vari-drive type motor. Such a motor will allow you to increase or decrease the pump capacity by turning a small handwheel.

In speaking to operators where both plunger pumps and "scru-peller" pumps are installed side by side, it is surprising to hear the conflicting arguments that the plunger pump will pump heavier sludges better than the "scru-peller" pump and vice versa. Questioning fails to reveal any substantiating evidence. There is no reason why one pump should be able to pump heavier sludges than the other if both pumps are properly installed and in good operating condition.

Operating Problems—and Their Solution

You have often heard the remark that you should pump sludges at a slow rate to prevent pulling a hole in the sludge blanket. Also that a centrifugal pump will pull a hole in the sludge blanket whereas a plunger pump will not. Operators who made experiments and who took sludge soundings before and after pumping with both types of pumps know that this is not true. A hole might be pulled in the sludge blanket by any type of pump regardless of the pump capacity. The cause of this trouble is sludge arching, and failure to flow freely to the intake line.

The sludge may arch over the hoppers, around the sludge pipe in the hopper corners, or the hoppers may be too large with flat slopes and of improper design. Sometimes frequent pumping will prevent arching or the pulsating effect of the plunger pump will break part of it loose. The best answer is to squeegee, otherwise the breaking loose of the arched sludge may allow the gas bubbles to float the sludge blanket to the tank surface. If this should occur, hosing will make it settle readily.

Squeegeeing the hoppers will also reduce the pumping time on rectangular clarifiers, and it will reduce the amount of water formerly pumped to the digester. The less water pumped to the digester, the smaller will be your supernatant disposal problem. Another good way to minimize your supernatant problem is to draw the sludge into a concentration tank. After an adequate settling period decant the clarified liquor and then pump the concentrated sludge. If the sludge mixture is allowed to stay in the concentration tank too long without any stirring, you may find the supernatant on the bottom and the sludge floating on top. The best way to solve the supernatant problem is at the original source, in the undigested sludge, where the liquor does not have the toxic effect that it has when it leaves the digester.

Where plunger pumps pounded excessively, air snifter valves have been placed on the suction side to form an air cushion within the pump cylinder. This does a good job in overcoming pounding, but it is not recommended. Its evil is that you are sitting on a potential volcano that might go off any minute because while you eliminate pounding, you are also pumping a certain amount of the air with the sludge into the digester, making possible an explosive mixture.

Perhaps you have been faced with the problem of prime failure. If it is a centrifugal pump with primer, check your priming equipment for leaky gaskets, sticky valves, or stuck floats. Also, make sure that seal water is flowing to the stuffing boxes. If it is a plunger pump, leaky packing might have to be replaced or tightened. Often the trouble may be a clogged line, or the suction pipe may be sheared off where it enters or leaves a wall.

Perhaps you are having trouble with a check valve at the foot of vertical riser pipe that is being clogged by grit and other material settling on top of the flapper. If the check valve cannot be relocated near the top of the vertical riser pipe or in a horizontal section, you may find that a clear water flushing connection on the suction side between the pump and gate valve of great help to you. By flushing the pipe line under pressure after each pumping you can force the grit and other material to a point where it will not cause any trouble. This flushing connection will also be a great help in case it is necessary to dismantle the pump or clean the ball or flap valves. It is much nicer to work on a pump full of clear water than sludge. It should be borne in mind that this flushing connection should be made in accordance with cross-connection requirements of the State Department of Health.

WATER SERVICE AND SEWER RENTS

The following interesting decision is reported by the Municipal Legal Information Service of the New York State Conference of Mayors and Other Municipal Officials:

"On October 11, 1940, the Court of Appeals, Richmond county, Ohio, held that the city of Mansfield had authority by ordinance and rules and regulations issued thereunder to shut off water at premises which are delinquent in their sewer rental payments. Pointing out that it is well settled that a city may shut off water for nonpayment of a delinquent water bill, the Court considers the direct question involved in this case of the power of a city to discontinue one service for failure to pay for another service, and holds that the sewer and water systems are so closely related as to be considered one transaction as the operation of the sewage system is dependent upon the water supply, therefore, it is reasonable to shut off water for nonpayment of a delinquent sewer rental bill. The court cites and relies upon the case of *Dodd* v. *City of Atlanta*, 113 S. E. 166, which reached the same decision as was reached in the instant case. *Gatton* v. *City of Mansfield*."

NICHOLS ENGINEERING & RESEARCH CORP.

60 WALL TOWER
NEW YORK, N. Y.

NERCO

UNIVERSITY TOWER
MONTREAL, P. Q.

POST-WAR PLANNING SHOULD BE STARTED NOW

When World War Two is won many American Communities will want to quickly provide for efficient disposal of sewage, garbage and rubbish. Lack of proper sanitary facilities before the war, and difficulty in securing materials for needed enlargements during the war, has made the public acutely conscious that sanitary, healthful and efficient disposal plants must be among the first public improvements built.

Nichols Engineering and Research Corporation has for years been a leader in the building of incineration plants. Nichols plants now in operation provide for complete disposal by incineration of the following materials:

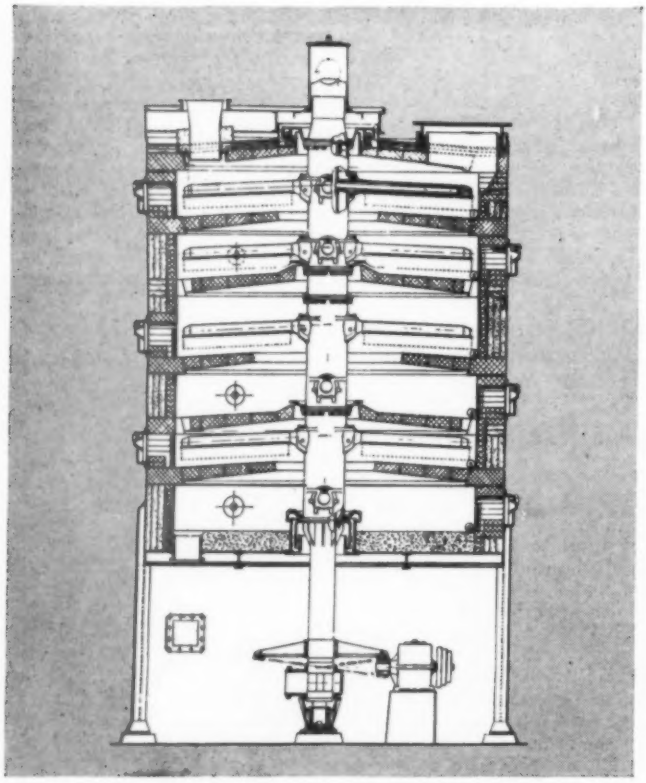
1—Incineration of Sewage Sludge

2—Incineration of Rubbish and Garbage

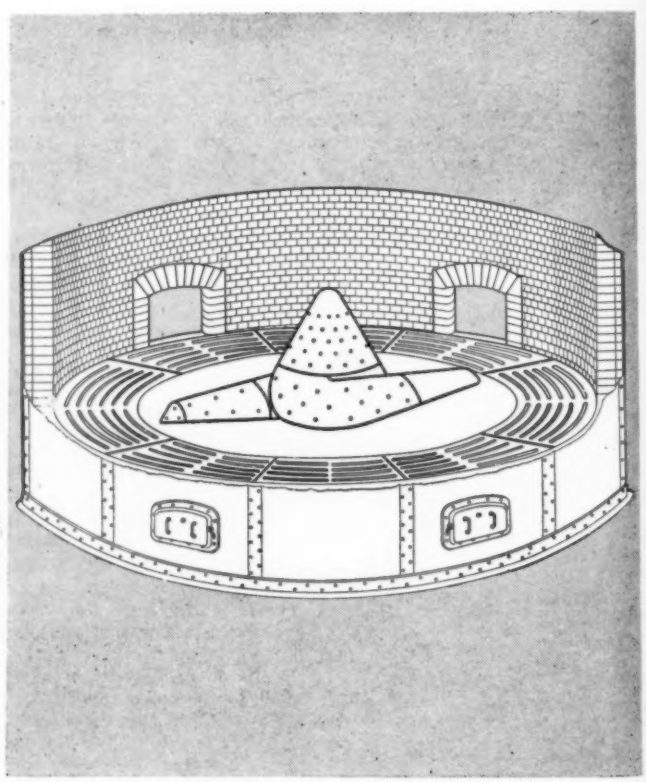
3—Incineration of Liquid Sewage Sludge

4—Incineration of Industrial Wastes

See that your community has the benefit of the latest developments in incineration practice. Have ready in your files, for use when the opportunity arises, the latest information on Nichols Incinerators. Start your "post-war" community planning now.



NICHOLS HERRESHOFF INCINERATOR
Bulletin No. 210 fully illustrating and describing this incinerator will be sent upon request.



NICHOLS "MONOHEARTH" INCINERATOR
Design and operation features of this incinerator are shown in Bulletin No. 212.

HOURLY LOAD VARIATIONS IN RELATION TO SEWAGE TREATMENT PLANT OPERATION

By ELSON T. KILLAM
Consulting Engineer, New York City

The wide variations in the hourly load arriving at sewage treatment plants, due to the combined effect of variations in sewage strength and in rate of sewage flow, have previously been discussed by the writer.[1]

Data then available were confined to two plants, both located in Georgia. Investigations recently conducted on two systems in New Jersey involving widely different conditions than those of the two systems originally described, indicate surprisingly similar load variations.

Tests of 24-hour duration with frequent flow readings and separate analysis of hourly or two-hourly samples emphasize the following conditions in these four systems:

(1) A substantial portion of the total daily load arrives at the plant in a comparatively short operating period—see curves.

(2) The hourly variations and per cent of the total daily load arriving at the plant in any given period are not markedly different regardless of whether the load be expressed in terms of flow and B.O.D. content—or, expressed in terms of flow and suspended solids content.

(3) Load variations from hour to hour are surprisingly uniform regardless of the size of the system or other factors which might normally be expected to create widely different conditions.

(4) Hourly distribution of load and variations therein have important effects on plant efficiency and on operating procedure with many types of treatment plants, particularly chemical plants. These variables emphasize the desirability of providing for flexibility in design to allow variable operation.

[1] "Hourly Load variations as a Factor in Sewage Treatment Plant Operation"—WATER WORKS AND SEWERAGE; July, 1934; pp. 237-240.

Studying the Load Variations

A convenient method of summarizing sewage load variations is by means of cumulative load curves. To obtain data for such a curve, samples should be collected throughout a full 24-hour period, preferably at intervals of 15 minutes or ½ hour. These samples should be proportionate to the flow and each group of samples comprising a period of one or two hours' duration should be separately analyzed. It is also essential to take flow measurements at frequent and coincident intervals. In this way the total pounds of suspended solids or B.O.D. arriving at the plant during each hour of the day, may be ascertained. Cumulative load curves may then be constructed by selecting, first,

TABLE NO. 1—DATA RELATIVE TO CUMULATIVE LOAD CURVES

Curve Number	Location of System	Type of District Served	Average Flow—M.G.D.	Estimated Tributary Population	Date of Test Period	Distance from Sampling Point to Most Remote Point in System—Miles	Method Flow Measurements (*)	Data Relative to Samples
"A"	DECATUR, GA. (Shoal Creek Outlet Sewer)	Strictly Residential: Separate System	0.167	2,200	4 p. m., Sat., Oct. 28 to 4 p. m., Sun., Oct. 29 1933	2.5	90 deg. V Notch Weir	(a)
"B"	RAHWAY, N. J. (Rahway Valley Joint Trunk Sewer for 7 Municipalities)	Separate System: Residential, with some Industries and some Business Districts	1.84	23,000	3 p. m., Mon., July 23 to 3 p. m., Tues., July 24 1934	7.8	90 deg. V Notch Weir	(a)
"C"	ELIZABETH, N. J. (Elizabeth Valley Joint Trunk Sewer for 12 Municipalities)	Separate System: Residential, with some Industries and some Business Districts	14.19	228,000	2 p. m., Thur., Aug. 2 to 2 p. m., Fri., Aug. 3, 1934	18.0	Venturi Meter	(b)
"D"	ATLANTA, GA. (Main Sewer Entering Peachtree Creek Plant)	Combined System; Residential, with some Industries and some Business Districts	15.22	110,000	8 a. m., Fri., May 3 to 8 a. m., Sat., May 4, 1933	8.0	Recording Gage at Station Rated by Current Meter	(a)

* All Flow Readings at half-hour intervals.
(a) Samples collected at half-hour intervals—each group of four composited and analyzed.
(b) Samples collected at half-hour intervals—each group of two composited and analyzed.

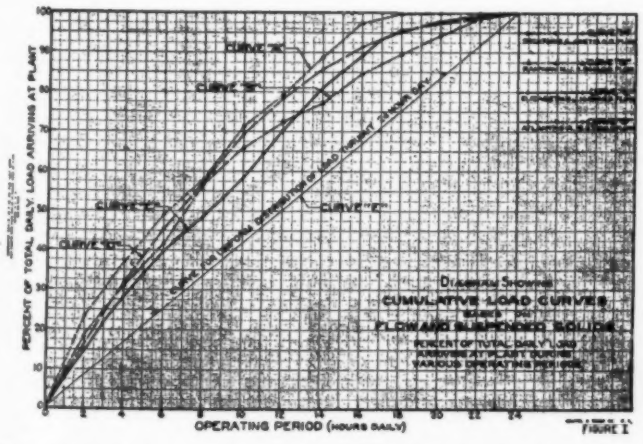

PERCENT OF TOTAL DAILY LOAD ARRIVING AT PLANT
OPERATING PERIOD (HOURS DAILY)
CUMULATIVE LOAD CURVES
FLOW AND SUSPENDED SOLIDS

Fig. 1—Cumulative Loads, Based on Floc and Suspended Solids

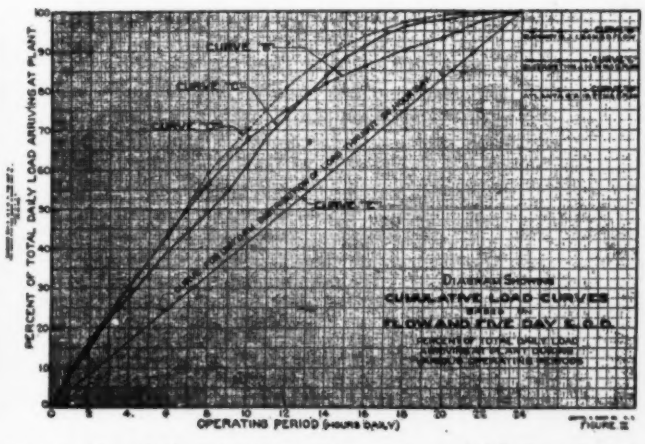

PERCENT OF TOTAL DAILY LOAD ARRIVING AT PLANT
OPERATING PERIOD (HOURS DAILY)
CUMULATIVE LOAD CURVES
FLOW AND FIVE DAY B.O.D.

Fig. 2—Cumulative Loads Based on Flow and 5-Day Oxygen Demand

the hour at maximum load, and subsequently taking each consecutive hourly load in order of descending magnitude, and plotting of 24-hour curve. Loads expressed in terms of flow and suspended solids content, or flow and B.O.D. content, or both, may be used for the study.

Typical examples of such curves, showing data for the four system investigated, are shown in Figures 1 and 2, the former being based on load determined by suspended solids content and flow, and the later upon B.O.D. and flow.

Statistics, showing the type of system, average daily flow, tributary population, and other information, for the four systems investigated, are shown on Table 1.

Similarity in Load Variations

In view of substantial differences in type and size of the four systems referred to in Table 1, the relatively small difference in the load developed in any given number of hours in each of the systems, is of especial interest.

The Decatur (Ga.) system, for instance, involved a sewage flow of only 0.16 m.g.d. with a population of only 2,200 people in a strictly residential area, and with the most remote point in the area served only 2½ miles from the point of sampling on the trunk sewer.

On the other hand, the Elizabeth Valley System involved a total flow of 14.19 m.g.d. from a tributary system comprising several hundred miles of sewers serving 228,000 people. Remote portions of the system are at least 18 miles distant from the point at which flow measurement and samples were taken.

It might well have been expected that in such an extensive system as the latter, the variations would be smoothed out and greatly reduced in magnitude before the sampling point was reached by the passing flow. Comparison of all four curves, however, indicates that in no instance, within a fixed number of hours of operation, does the total cumulative load arriving at the plant vary by more than 13 per cent. Examination of the curves also discloses that the distribution of the load, based on suspended solids, agrees very closely with the load based on 5-day B.O.D.

What It Means

The similarity of these curves indicates that load variations in substantial proportions may be expected on every sewerage system. These variations and their effects are accordingly important in the design and operation of sewage treatment plants, in the measurement and evaluation of treatment plant efficiency; and, in the collection of river samples below sewer outlets during investigations of the pollution of receiving streams.

OPERATING LOG FOR A SMALL SEWAGE PLANT

By A. A. HIRSCH
State Department of Education
Baton Rouge, Louisiana

THE desirability of complete record keeping about a sewage plant is generally recognized, but operating logs are often so bulky, and time consuming to attend, that operators frequently regard them with disfavor. A properly planned log should contain only pertinent and useful data; its form should be streamlined to expedite the recording of necessary figures. Excessive use of columns to record other than regularly recurrent data should be avoided. Aid should be included for easy reference to records of previous periods.

The application of these principles to the design of a daily operating report for a small plant providing primary settling in an Imhoff Tank and secondary trickling filter treatment is illustrated in the accompanying drawing. Obviously, the information carried and form best adapted will vary with the size and type of plant; however, the essential points as enumerated below can always be employed to advantage. In the illustrated log will be noted columns for customary daily data; a sheet covers a month's operation. As in many plants, the blanks are printed in different colors for duplicates or triplicates, with stiff cover binding. Groups of related data are separated by heavy vertical ruling; every fifth date line is also drawn heavy to facilitate space location. The column headings are all self explanatory, excepting the codes, which will be discussed below. Mechanical and operational data are segregated from the chemical test results. Customary rulings appear at the bottom of the sheet for the monthly summary. A liberal width is reserved in the remarks column for infrequent details or a condensed diary. Additional notes of this character can be written on the back of the sheet with proper reference on the corresponding date line. The extra column, preceding the "Remarks" column (now blank), is provided for possible future need.

Distinctive Features

It is to the following five features, some of them unique, that attention is specifically directed:

1. *Size of Sheet.* The sheet measures 11 by 16⅝ inches. This is a convenient size, its length being the same as that of an ordinary letter size typewriter sheet, while its width is slightly less than double a letter sheet. Records detached from the blank book may be folded slightly beyond the middle to fit a file folder exactly as would a letter. Using the same crease, the left margin extends out as a single thickness almost the full ruled width, thereby permitting perforation to fit ordinary size looseleaf binders.

2. *Double Date Column.* Date columns are printed at both sides of the tabulated data in order to locate particular date spaces by easy glances and with less chance for error.

3. *Coding.* All routine descriptive remarks are keyed to condense this information. The identity and sequence of units in service are recorded by code in the proper column. Points of chlorine application are denoted by a key letter placed behind the total quantity used. A suitable legend explaining the code is placed off to the right of the sheet so that the information will always be intelligible. By way of example, the notation in the units in use column T2E-R1-F2 would signify on that date Imhoff tank No. 2 flowed eastward and rotary filter No. 1 with final settling tank No. 2 were in service. In the chlorine quantity per day column the data 5.5-EF would mean that this weight of chlorine, in pounds, was being divided between the Imhoff effluent and the final settling tank.

4. *Occasional Information Boxed Separately.* Infrequent data are posted in a side space to conserve room in the main taubulations, where this type of information would be difficult to locate. A special tabulation is made to the right of the sheet to record sludge drawoffs. Service connections also are displayed in an individual box.

5. *Marginal Indexing.* Marginal tabs for quick location of past records in bound volumes of monthly sheets is provided by printing the edge of the sheet with names of the months. In use, all other names except for the month concerned are cut off. If the sheet is folded during filing, the operator may print the name of the month on the reverse of the tab also.

A log of this type is presently giving satisfaction at the Rayne, La., disposal plant, where Mr. E. J. Bertrand is superintendent, and Mr. Pat Spell, operator. With functionally arranged sheets, record keeping is expedited and the value of previous logs for reference is enhanced.

SMALLTOWN, LOUISIANA

SEWAGE TREATMENT PLANT OPERATING REPORT

MONTH OF _____ 194__

Date	Sewage Flow MGD	POWER Reading KWHr	POWER Consmpn KWHr	UNITS IN USE (CODE)	TEMP. °F Air	TEMP. °F Sewage	Rainfall in.	SETTLEABLE SOLIDS ml/L Raw	Settled	Final	% Removed	pH Raw	Settled	Final	Sludge	Relative Stability %	CHLORINE Cylindr Weight Setting	Quantity #/Day	Point Applied	Dose ppm.	Residual p.p.m.
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SLUDGE WITHDRAWLS Date	Imhoff Tank No.	Amount Cu. Ft.

Service Connections at End of Month

CODES

Plant Units
T - Imhoff Tank - 1-2
Flow - (E)ast - (W)est
R - Rotary Filter - 1-2
F - Final Set. Tank - 1-2

Chlorine Points
R - Raw Sewage
E - Imhoff Effluent
F - Final Set. Tank

_____ OPERATOR

_____ SUPERINTENDENT

JAN. | FEB. | MAR. | APR. | MAY | JUNE | JULY | AUG. | SEPT. | OCT. | NOV. | DEC.

W. W. & S. — REFERENCE & DATA — 1948

Operating Log for Small Sewage Plants

ALLEN-BILLMYRE CORP.

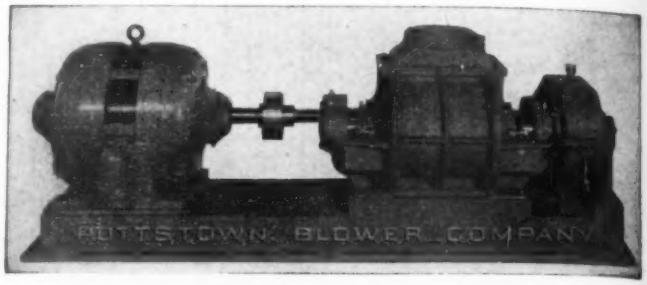
449 Fayette Ave., Mamaroneck, N. Y.

BILLMYRE Centrifugal or Turbo Blowers and Exhausters; POTTSTOWN Rotary Positive Displacement Blowers and Vacuum Pumps; EXIDUST Central Vacuum Cleaning Systems and Portable Vacuum Cleaners

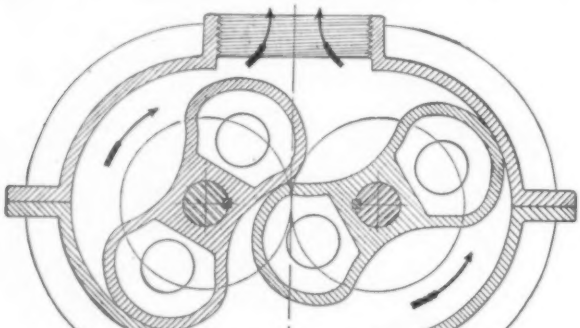
POTTSTOWN Rotary Positive Displacement Blowers and Vacuum Pumps

Applications: Sewage treatment, supercharging liquid agitation, pneumatic conveying, drying, air supply for furnaces, forges, ovens, cupolas, etc.; where a relatively constant volume of air or gas is required at variable resistance or pressure difference.

General Design and Characteristics: These machines have two impellers which rotate with close clearance in opposite directions on parallel shafts. Correct timing of impellers is provided by gears which run in a sealed-case oil bath. As each impeller rotates, its two concave portions carry a pocket of air or gas from the inlet to the discharge. Therefore, there are four impulses of air or gas at each revolution; and these impulses merge into a practically continuous flow at rated speed. Maximum volumetric efficiency is provided by close accurate clearance between impellers and casing.



Electric Motor-driven Pottstown Blower for Sewerage Service



Principle of design of Pottstown Blower... two impellers which closely engage and carry entrained pockets of air or gas from intake to outlet at each revolution

Sizes and Ratings: These machines are built in a wide range of sizes to develop pressures between ½ and 12 psi or equivalent vacuum, and for drive by electric motor, steam turbine or gas engine.

Described in Bulletin P-100.

BILLMYRE Centrifugal or Turbo Blowers and Exhausters

General Design and Characteristics: Similar in principle to centrifugal pumps. The impeller and shaft assembly is the only moving part, and there are no wearing parts. Constant pressure is automatically maintained over full capacity range. No controls are required for pressure, power or relief, because the pressure never exceeds the maximum for which the machine is designed. Operation is smooth, quiet, and free from pulsation. No internal lubricant is required, hence air is delivered clean and dry. Original efficiency is maintained indefinitely.

Applications: Air supply for furnaces, ovens, kilns, and cupolas; liquid agitation and aeration; cooling, blowing and spraying equipment; for boosting gases and air-gas mixures. Described in Bulletin I-100.

Model SG Billmyre Blower—one of many available types

ACTIVATED SLUDGE BULKING*

Some Considerations as to Causes and Corrective Measures

By L. H. ENSLOW

Editor, "Water Works & Sewerage"

In presenting this informal discussion, and my own opinions with regard to causes of bulking of activated sludge, I shall also offer suggested corrective measures for bulking. The matter of "sticking my neck out," so to speak, gives me little concern if, by such willingness to expose myself, I can provoke more consideration and study of this most vexing and important problem of operation. And, in my belief, of plant design also.

What Constitutes Bulking?

The first question is—"What constitutes bulking?" When I first entered the sewage field I had heard of bulking sludge but I had no idea what it looked like. I thereafter discovered that there was more than one type of bulking. These types, in my opinion, represent two entirely different causes and effects. One is peptization of sludge floc and the other is really bulking (swelling) of sludge. True bulking of sludge means that the particles have become hydrophyllic. This means that they have taken up water, such as leather will, and swelled to the point that the gravity is so low as to cause the bulked sludge to rise in the final clarifying tanks. When in this condition, slight disturbance and increased velocities will cause it to pass out over the weirs of such sedimentation units. If you examine this sludge closely, you will likely also find that the particles are buoyed up by myriads of tiny gas balloons; i. e. very small gas bubbles of microscopic size. To cite an example, I have observed that salt water oysters subjected to fresh water will exhibit this same hydrophyllic phenomenon of absorbing water. One may say that, like the oyster, the sludge has become "bloated."

Let us consider some of the qualities and characteristics of an activated sludge beginning to bulk. Under the microscope you find that amongst the sludge organisms the protozoa have become sluggish. Instead of working vigorously, (for instance, the stems of bacticella and the like no longer coiling and coming back with a snap as they do when in a healthy condition) you will find that they are lazy and not at their job of assimilating bacteria and what not. I do not know whether they do assimilate anything other than bacteria, but at least they are not active when the sludge is ailing or, is it a case of "vice-versa."

Following this you begin to get peptization or bulking, as the case may be. Bacteria increase, and there is an oxygen deficiency. Nitrates are going down, whereas ammonia is increasing. There is a loss of characteristic brownish color of good activated sludge. In due time the effluent begins to take on the odor of hippuric acid ("hippo" meaning horse). However, the effluent is splendid for a time after bulking of the sludge begins to appear. It is crystalline clear for a while and represents a very excellent effluent. If one could "put the brakes on" at this point and hold the condition, he would have optimum activated sludge operation from an economy standpoint, and as high an efficiency as he could expect. However, the difficulty is that he cannot easily stop the bulking-ball that has started rolling.

The next thing that happens is that the bulking becomes very pronounced. With increase in sewage flow, the sludge blanket is disturbed, and much sludge goes over the weirs into the stream. The liquid portion of the effluent, even yet, is not bad but becomes so in time, if the cause of bulking is not corrected.

What Causes Bulking?

Now let us consider some of the causes of real bulking (swelling), as distinguished from peptization of flocs and milky effluent, such as poisoning of bacteria as enzymes may produce. The universal answer is the deficiency of dissolved oxygen reserve and nitrates in the aerating units or in the final settling tank. The latter may be as important as the former. In other words, the way I look at it, the problem becomes a question of oxygen "banking." Picture an aeration tank (sketched on the black board). Whether by air diffusion mechanically or by air blowing, in the aeration tank liquor you are "banking" dissolved oxygen. With this banked oxygen you can meet demand notes by withdrawing or checking. The notes are the oxygen demand "notes" of the sewage plus that of the sludge in the mixed liquor. If your balance is steady, or on the increase, and your withdrawals are gradually on the decrease through the aerators, you will always have at all points in your "oxygen bank" a residue of dissolved oxygen on which you may draw. Such means solvency and will keep you from going absolutely oxygen bankrupt. Assuming this condition can be maintained, you will never find yourself "in the red"—at least as to performance if not in respect to costs. If you do overdraw your oxygen account but within an hour or so you replace the overdraft, adding perhaps a little surplus, you are still safe from your principal debtor whose initials are B.O.D. In commerce the criterion, of course, is how quickly and adequately you are able to do your banking, that is, how quickly you can make your deposits to meet the on-coming drafts or checks. Just so it is with the balance between oxygen reserve and oxygen demand in an aeration unit, which spells solvency, or bulking bankruptcy.

Another analogy may be made in citing two runners—one a strong runner and one a weak runner. Should the strong runner stub his toe just as he takes off from the starting point, he may have a hard time to overcome the set-back and may even come in, a limping loser. Overcoming such a handicap, even against weak competition, is frequently very difficult. So it is in financing, that is, in making up bank deficiencies; and, so it is in the activated sludge process in making up oxygen deficiencies which reach serious proportions near the influent end of the aeration units.

The rapid oxygen demand of the sewage, as I stated, is the critical thing. This occurs at the inlet end of the aeration unit and represents the sudden demand notes drawn on the oxygen in the bank. I have seen activated sludge plants operating very nicely on very strong sewages, as long as the input remained on an even keel. On the other hand, I have seen activated sludge plants confronted suddenly with varying organic loads, and the process has gone all to pieces with startling rapidity. One would not think that these periodic loadings could disrupt the process the way they do. Of course, what I have said is particularly true of small plants. In large plants it takes much more to cause trouble than in smaller ones, for the reason that your bank is stronger and the "balance" is not so easily upset.

Sludge vs. Liquor.

Too much sludge carried in the aeration tank has an effect similar to too much of an organic load in the sewage coming in. However, in my opinion, the sludge loading does not begin to compare with the influent loading in importance. The reason is that it is a more stable load and is subject to control. It is not flashy unless somebody permits the sludge to become partially septic; then, of course, it has an explosive oxygen demand which is disastrous. The return of supernatant liquor from digesters is a tremendously bankrupting practice as many have learned. More about this later.

Another cause, I think, of activated sludge bulking or perhaps of moderate bulking is a lack of inorganic matter in the sewage. I refer now to material like iron, salts, silt or clay, and other materials which tend to give weight and coalescence to floc of any sort, whether activated or not. As a matter of fact, I consider the activated sludge process to be as much of a natural coagulation process as it is of an oxidation process. The first stages of coagulation and adsorption are by far the most important stages in activated sludge, and if we could chop it off at some point before nitrification sets in (and hold it there) we would have the greatest amount of work for the least number of dollars for operation. Unfortunately, no one has found the formula for this procedure, the nearest to it being the Guggenheim biochemical process which involves a combination of chemical precipitation and bioflocculation.

I might mention that recently there has been considerable work done on the use of silica as a coagulation aid. Perhaps many of you have heard that in water treatment practice silicates may be

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used for improving flocculation with alum and iron, and so in sewage treatment it may well be that something of this nature will be found to play a part in activated sludge coagulation. I cite one indication that silica may have a distinctive bearing. I have frequently observed cases where clay or silt enters sewers as a result of rainstorms. And, almost immediately the coagulation phenomena of activated sludge, the settleability of the sludge, and consequently the important sludge index, seem to improve. I am wondering if perhaps the colloidal silica content of clays may not have a bearing on activated sludge coagulation as it does on alum and iron coagulation. I consider this an interesting problem for some student or researcher to undertake; namely—"The Effect of Various Inorganic Compounds on Activated Sludge Behavior."

Another reason for the bulking of sludge is too little oxygen input in the sludge reaeration channels, if reaeration is practiced. In other words, your bank balance is decreasing rapidly and can decrease extremely fast if you do not keep well ahead of the sludge demand, so to speak. Sludge may have (and frequently does have) a rapid oxygen demand as it comes from the final tanks. In other words, if you are returning your sludge slowly to obtain a concentrated return, you are tending to build up in that sludge an increased and a rapid oxygen demand. Should you not have enough oxygen to take care of the demand immediately, and not enough carrier liquor in which to "bank" this oxygen, you will never catch up. By putting into the inlet of the aeration unit an oxygen deficient sludge you have lost ground before the mixed liquor enters the aeration tank and, in my opinion, that is the reason for the difference in arguments, pro and con, for reaeration of sludge. A new theory is that reaerated sludge must be kept nourished with fresh sewage input. Some will tell you that reaeration is worthless and that it is really harmful, whereas others say that they cannot get along without it. I believe it to be just a matter of the balance of oxygen reserve as to whether or not an operator needs or does not need reaeration of sludge. The British practice is to reaerate and return very thin sludge. The freshness and thinness of their sludges may account for their successes with reaeration.

Another point is the ratio of settleable solids to non-settleable solids in the sewage. I mention this point for the following reason. In Great Britain one of the remedies in sludge bulking is to by-pass the long period primary tanks, thus diverting more suspended solids into the aeration units and also securing a fresher sewage, with benefits later to be cited.

Grease and oil have an effect on sludge bulking. Grease or oil mix in with the activated sludge floc and coat the particles, affecting the specific gravity of the sludge if nothing else. Many engineers think it has considerable bearing on the bio-activity of the sludge. Studies now under way will tell us more about this later, but grease separation appears definitely beneficial.

There has been a suggestion that yeast is harmful and results in bulking; that is, yeast from breweries and other places. Some British authorities seem to think yeast is very harmful. I think possibly the yeast growth is the index of something else that is worse. I refer to the oxygen demand, and more particularly to the demand rate of the waste which contains the yeast; but this again is a personal opinion and needs verification. Where yeast is, there is usually a lot of organic matter with it.

Then we come to filamentous bacterial growths, of which we hear so much, such as sphaerotilus and leptothrix. In paper mills they call these growths "slime." I will speak a little more about filamentous growths later. They may be the cause of bulking, but I do not believe they are the direct cause. I think they are indexes, again, of a deficiency of oxygen which is the direct cause of bulking.

Then, of course, there is carbon dioxide. Gas liberation, carbonaceous fermentation and acid production unquestionably have an effect on bulking. Septic sewage and supernatant digester liquor, in my opinion, is probably one of the most serious factors contributing to bulking in the greatest number of plants.

The Effect of Septic Sewage.

I was very much interested in an article that appeared in the July, 1938, issue of "Water Works and Sewerage." Written by Dr. Heukelekian, of the New Jersey Experimental Station, it more or less fights this battle for for me. I have claimed a lot of things that were bad of septic sewage, but I did not know what the New Jersey authorities have revealed—namely, "That once sewage has become septic it will take up oxygen only one-half as fast (approximately) as the same sewage in a fresh condition." In this revelation many will be surprised and take on an increased respect for septic sewage and supernatant liquor. In his studies of the effect of septic sewage on activated sludge, Dr. Heukelekian took septic sewage, boiled it to kill all life and then reaerated it. He found that the same sewage in a fresh condition, treated in the same way, would take up twice the oxygen; that is, would take the oxygen at twice the *rate*, the latter being the important revelation. The amount of oxygen required is not nearly so important as is the rate at which it is required, and the *rate* at which it will be dissolved and "banked" in the liquid phase.

With the above in mind, septic sewage reaching a plant in hot weather reduces the capacity of the storage reservoir of dissolved oxygen by about fifty per cent. For instance, Dr. Heukelekian found that in twenty minutes of aeration, fresh sewage (boiled) would take up 3 parts per million of oxygen (approximately) as against 1.8 parts per million for *septic* sewage treated in the same way. You will note that this is almost two to one. But this is not the whole answer. The important consideration is, that if this happens every twenty minutes from the influent end of the aeration tank through the effluent end of the tank, and if the aeration period is six hours, the effect is considerably multiplied, and interest on the deficit is compounded. Let us put it this way. The dissolved oxygen "balance" is in pretty bad shape before you get to the end of the tank. You have not accumulated anything, because the oxygen is going out at a rate you cannot control, and this rate is faster than it can be deposited. This constitutes about the most interesting disclosure I have seen in the way of an explanation of why it is desirable and many times necessary to avoid septic sewage. We do know that in hot dry weather more than one activated sludge plant operator goes home at night and prays for rain. When he gets rain he knows he is on safe ground, at least temporarily. In my opinion, dilution is one of the best corrections for septic conditions, and it is not a far cry to recommend that a handy creek be bled into a sluggish sewer in hot dry periods.

Supernatant liquor from digestion tanks, if discharged to the inlet of the plant, causes an effect similar to septic sewage, but there is so little of it that you do not begin to feel the cumulative effect that you would if all of the sewage is septic. However, the fact is that supernatant liquor does cause serious upsets of the process. Further, it probably encourages the growth of organisms in the sewage which I believe those of normal activated sludge do not like as associates, and likewise adds toxins.

Peptization of floc can be caused by different things, but you usually find that this condition is caused by a poison of the decolloidizing elements or organisms in the sewage and sludge. In other words, the clotting effect is hurt and you do not get efficient flocculation. Peptization results in a whitish milky-looking effluent.

Correctives

Now consideration may be given to possible correctives and there are several of them. Some of them work and some do not. Some work here; some work there; and some work nowhere. The first thing to try is more air—if you have it. The next thing is lesser amounts of return sludge, reducing the amount of solids in the sludge rather than the volume. If anything, you usually have to increase the volume of return sludge. The third measure, of course, is less sewage. That last seems to be a universal corrective because by-passing has been the most prevalent method of correcting difficulties at activated sludge plants. Adding clay is another method and the use of chlorine still another.

I was extremely interested in another phase of Dr. Heukelekian's paper. His conclusion reads, "The dissolved oxygen level in the activated sludge process is the resultant of the supply and demand of oxygen. The supply is governed by the method and rate of aeration available." Further quoting from his conclusion he says, "Another factor that influences the level of dissolved oxygen is the temperature. As the temperature increases, the amount of oxygen that can be dissolved in the liquor decreases, and at the same time a greater demand exists due to increased biological activity. Thus, the critical periods in the operation of an activated sludge plant appear in the warmer season." If you add to this condition septic sewage, the operator's difficulties are further increased. On both scores the mixed liquor naturally will not dissolve as much oxygen.

Again quoting, "Theriault and McNamee have estimated that 35 per cent of the dried activated sludge is represented by bacterial cells. * * * The bearing of these generalizations on the maintenance of dissolved oxygen in the activated sludge process is obvious. As long as aerobic conditions are maintained, the process of aggregation of sewage colloids will take place, resulting in a well clarified effluent and an active sludge. When there is no dissolved oxygen present the process of aggregation will cease, the opposite process of dissolution will take place, breaking up the aggregated sludge floc."

Dr. Heukelekian then concludes by saying, "Until more definite information is available, indicating that with higher dissolved oxygen concentration a much more rapid purification is brought about, a minimum of 0.5—1.0 p.p.m. dissolved oxygen maintained at all times and in all sections of the aeration tank should be considered as the most economical range."

Other correctives have been seasonal treatment of industrial waste to reduce the load on the plant. Lime have been employed for pH correction, but I will say that my experience has been that the use of lime offers very temporary relief. It does seem to shrink the sludge temporarily, but you soon find that the effluent becomes milky and conditions become unsatisfactory again.

Other methods than by-passing include reaeration, more rapid sludge return, which I have touched on, thickening of excess activated sludge going to the digesters, and stage digestion of sludge, which gives a less objectionable supernatant liquor.

Sludge Thickening.

As to sludge thickening, it was first developed at Los Angeles and later used at Phoenix, Arizona, where it proved a "life-saver." Topeka practices it as does Columbus, and Baltimore is including it in the design of improved works. When sludge thickening is practiced, the sludge is not returned to the raw sewage for settling in the primary tanks where it may become degraded and much of it passes over into the aeration tanks. To my mind, it is extremely questionable practice in activated sludge treatment, and poor economy to return this material to the sedimentation units. A good many people have argued contrary to this, but I have observed many activated sludge plants, have studied them, and have thought about them a lot. When I see this bulky, half-rotten sludge which was put into the tanks as good activated sludge, which laid on the bottom as long as it could and which finally is swept through to the aeration units, I am certain it has a tremendous oxygen demand. It has a tremendous chlorine demand and anything that has a tremendous chlorine demand likewise has a very high oxygen demand. I do not know whether the organisms contained have any effect on the aeration tanks or not, but I do feel that the needless load on an activated sludge plant, caused by this manner of handling sludge, is absolutely unnecessary. It is necessary to take all the load coming to the plant (the sewage) but why should you take a good activated sludge and let it go through partial digestion and put it back into the aerating tanks again during periods of peak loadings?

"Freshening."

Sewer flushing or sewer dilution has always been helpful where septic sewage is the cause of the trouble. I have often said that any operator is fortunate who has the trunk sewer to his plant passing under a brook or stream. By knocking a hole in the sewer and by fitting it with a suitably constructed valve, he is able to realize the value of sewage "freshening" and sweeping sewer flows. It may even pay to install pumping equipment and pump water from a stream, or he might even pump some plant effluent back into the incoming sewage. In my opinion, it may cost less to pump water into the sewer than it does to pump air for aeration purposes and there is little question but that the operator will sleep better at night.

Sludge Return Control.

Now, about sludge return reduction. This seems to be an extremely important item at times. First, the operator keeps down his solids and, second, he draws his activated sludge back fast enough so that he gets more fresh liquid to dissolve more oxygen in the "banking" process. Many of you may be surprised to know that at some plants the return sludge is 50 per cent to 100 per cent by volume. Now why do the operators do this? It is more or less for the same reason that I would like to have a creek pass over the trunk sewer to any activated sludge plant which I would have to operate. The increased return sludge volume naturally will reduce the aeration period, but a 6-hour aeration period does not necessarily mean a thing in the world. One may get better results in two and one-half hours if he knows how. More liquid is delivered to the aeration units, thereby supplying a "blotter" that will absorb more oxygen and hold that oxygen in a higher concentration (probably three times as much) than is possible with strong or septic sewage. Naturally, the total oxygen demand is the same but the operator has been able to put more "money" in the bank. While the total draft remains the same, he avoids oxygen bankruptcy. The whole point is this: Put something into the aeration tanks that will dissolve the oxygen input and then furnish the tank with all the oxygen (air) you have.

There are some operators who say that they want to have a "sludge reserve" for return at augmented rates when troubles appear. Well, all I have to say is this: They are just inviting a lot of trouble. It is ideal (on paper) to have a big reserve sludge tank that can be kept thoroughly activated all the time from which the so-called "shock troops" may be obtained. I know one plant (London, Ontario) working on this basis, but it costs the municipality a lot of money. Actually what those fellows do in London is to return super-aerated sludge to the sewage in the aeration tank. This aerated sludge acts rapidly. When I heard of the theory of zeolite action by sludge, I thought right away about the London scheme, because the operation at this plant is probably as good an example of such action as anything I have seen. Sludge is reaerated for about twelve hours. The contact with the sewage is less than two hours. There is no question but that a good plant effluent results, but the power requirement certainly reflects the high cost of sludge reaeration. And, every so often something has to be done to retard the activity of sludge in the reaeration stage.

Chlorination.

Now this discussion has developed to the point at which I will refer to chlorination and its uses pertinent to activated sludge. First, considerable can be accomplished by chlorinating up-sewer to suppress septic action in sewage. This has been demonstrated better perhaps in Los Angeles County than anywhere else. There it was impossible to treat more than about one-half the sewage flow until up-sewer chlorination was instituted. It was really remarkable how readily the sewage quality was modified and the entire flow could be handled once chlorination was established.

Then, there is return sludge chlorination, which was really "born" in Ohio, and credit goes to E. E. Smith of Lima and to M. W. Tatlock of Dayton for having initiated this procedure.

After Smith and Tatlock told us about chlorination of return sludge the next place at which we heard of its use was at Lancaster, Pennsylvania. I may say, that too much chlorine in the chlorination of return sludge results in peptization, and a "milky" effluent is an indication of such. However, return sludge chlorination certainly has possibilities, as has been demonstrated at other important plants. At Lancaster, aero-chlorination is now being used for grease separation and Mr. Weist, superintendent, has written me that he believes aero-chlorination is better for his purpose than return sludge chlorination, for the reason that it separates grease which previously he had found in his activated sludge. In other words, it is doing two jobs, so to speak.

Phoenix, Arizona, has been practicing concentration of waste sludge for some time, sending it directly to the digester and chlorinating the digester supernatant liquor for return to the aeration units. This has done a lot of good, but now, in addition to this practice, the Phoenix authorities have gone to chlorinating the return sludge.

Now why does this chlorination of return sludge work? I again wish to emphasize the fact that I advance *probable* reasons, largely personal opinions. First of all, bacterial control is accomplished, that is, control of the growth of saprophytic organisms, not the organisms we see on 37 degree plates but those that take up so much oxygen. In this group are the bacteria of fermentations and the sulphate splitters. They produce a lot of CO_2, a lot of hydrogen sulphide, and a lot of trouble for a lot of operators. I liken their presence or absence to cold weather versus hot weather conditions. In other words, if you can suppress bacterial activity through your aeration tanks, these organisms are not present to draw upon the oxygen and to dissipate it rapidly. There is less oxygen demand in the absence of these organisms. For one, I do not believe that saprophytic organisms, as a general rule (certainly not anaerobic organisms), have a place in a sewage plant, other than in the digestion tanks.

The second reason why chlorination of return sludge works is that control is had of filamentous growths. I frankly believe sphaerotilus and other slime forming organisms which we find in activated sludge (like pH and dissolved oxygen) furnish an index of conditions. I believe the deficiency of oxygenation is the real cause of bulking and that filamentous growths, since they will not grow unless a low oxygen balance is had. are principally an indication of a deficiency of oxygen. Chlorine suppresses the rate of dissolved oxygen disappearance and maintains the oxygen balance. In doing this, filamentous growths are controlled. I have seen these biological growths in streams below sewer outfalls, as many of you have, but they disappear just as soon as you begin to get to a stable or balanced oxygen condition. The activated sludge process, with controlled application of chlorine to return sludge, does not "stub its toe" at the inlet end of the aerators and, therefore, does not come limping down

to the finish line. This practice has accomplished much at Lima, Ohio; Phoenix, Arizona; and Houston, Texas. As a matter of fact, I believe that at Houston the greatest benefits of all have been accomplished by chlorination of the return sludge.

In this connection I will first read from a letter which I recently received from D. Travaini, superintendent, relative to an experience at Phoenix, Arizona. In part he says: "In April of this year we had a beautiful case of bulking. Our convention (Arizona Sewage Works Association) was three days off and we weren't happy with our results. The aerators were so full of filaments that the sludge had completely lost its identity. We ran an emergency chlorine line from our chlorinator to our reaerator and in five days our bulking was completely gone. One hundred pounds of chlorine per day did the trick. The chemical dosage (based on volume of sludge returned) amounted to 5 to 6 p.p.m. of chlorine. Since then we have played around with chlorinating our sludge. Our plant is up to design capacity, but in spite of this fact, by using 75 to 100 pounds of chlorine per day, we have been able to eliminate one aerator from service at a saving of about $50.00 per month, in favor of chlorine over power. We had a serious breakdown in the aerator in question so we had to follow the procedure mentioned but it worked, so we planned to continue this practice."

Houston, Texas, has for some years suffered with an overloaded activated sludge plant. Although at this time the plant is in the process of being enlarged, the boys down there are due a lot of credit for keeping the present plant on as even a keel as they have. I wish to read from a paper by William Pralle, assistant city engineer in charge of sewers, at Houston. This paper, which deals with the operation of the sewage treatment plant, was presented before the Texas Water Works Association. I quote from the paper as follows:

> "Another advantage of an activated sewage treatment plant is that with a little larger operating cost, from about $1.50 to $2.00 per M.G. according to the delivered cost of chemicals, the plant capacity can be increased without spending a young fortune for permanent construction of extensions.
>
> "To make myself clear, I do not mean to hold back on proper capacity to meet average daily flow of activated sludge plants, but do believe in having the plant equipped with a chemical unit to be used in emergencies, and at times when the plants appear to be overloaded.
>
> "The South Side Sewage Treatment Plant in Houston, employing the activated sludge process, has been increasingly overloaded in both aeration and sedimentation capacity for several years. The result has been that the general difficulty, commonly referred to as 'bulking,' was almost continuously present. In the Spring of 1937 a plan for experimentation was adopted, whereby chlorine and chlorinated copperas, or either one of these chemicals as found best by experience, was to be applied during the treatment process.
>
> "Chlorine alone has been applied to the returned sludge at Houston, just prior to mixing with the incoming raw sewage, since May 16, 1937, and the resulting improvement in the plant effluent has been very satisfactory.
>
> Only a portion of the data collected is in form for presentation here, but the following indicates the general improvement so far realized in the plant effluent.
>
> "The average 5-day B.O.D. of the plant effluent for four months prior to chlorine application was 66 p.p.m. and the filterable suspended solids 96 p.p.m. The average B.O.D. determined daily for the two weeks, May 16th to June 1st, was only 37 p.p.m., or almost half. And, the filterable suspended matter for the same period was likewise cut practically in half.
>
> "Chlorine was applied at the average rate of 5.34 p.p.m. to the returned sludge. At this particular plant the volume of returned sludge is, for operating reasons, much higher than is usually practiced in per cent of raw sewage treated. The average aeration time at this plant is practically 2½ hours, so that the reduction of the volume of returned sludge, made possible by chemical treatment, has produced part of the benefits.
>
> "During chlorine application microscopic examination made daily has shown a distinct reduction in number of filamentous organisms in the sludge. * * *
>
> "It has further been definitely found that effective control of chlorine application is necessary for best results, and that over-chlorination will produce undesirable conditions from which recovery is slow."

Then, in his letter referring to an operating record chart attached, Mr. Pralle replies to questions asked by me as follows:

> "You have referred to some of the shortcomings of the chlorine application, or conditioning of returned sludge. Excepting the added cost, the only comment we can offer at present is that a definite 'overdosage' is possible and should be guarded against. The limits of the amount which can be applied with benefit have not been determined, but our experience has shown that a very cloudy appearance of the effluent can be obtained and this has been relieved only by reduction in the chlorine quantities.
>
> "During construction incident to enlargement of our North Side Plant, chlorine application has been in progress for about 90 days. The data obtained are now being compiled, and these promise to given even more satisfactory information.
>
> "Questions of 'Cause and Result' have been found which have not been answered to our satisfaction, so that all comments are welcome. For instance, attention is directed to the greater difference between suspended solids and B.O.D. content of plant effluent during chlorination than prior to chlorine application. (Mr. Pralle is referring to the fact that B.O.D of the effluent improved more markedly than the suspended solids reduction would indicate.—Ed.) Our laboratory methods in all instances have been the same, and two questions are: (1) What has happened to the B.O.D. of those suspended solids which tests indicate are present in the effluent? (2) If the B.O.D. test of the effluent has been vitiated by this small amount of chlorine (as some seem to think is the case) why, then, is the B.O.D. reduction still evident in the analyses of water of the receiving stream below the plant?"

The reason I have read excerpts from Mr. Pralle's paper is to call attention to the fact that as long as the plant is performing better, the effluent is good, and the dissolved oxygen conditions downstream are good, an operator need not be concerned as to the exact technical explanation of the chlorine effect. However, it would be interesting to have more exact knowledge of the effects. This paper, with the accompanying analytical data, indicates that when you have difficulty in keeping your oxygen input up to a satisfactory level, it is a pretty good idea to return a thin sludge at higher rates, than a thicker sludge [longer removed from the aeration cycle) in lesser volume. The interesting thing with reference to the data at the Houston plant is what happened to the B.O.D. of the plant effluent when chlorination of the return sludge was stopped. As Mr. Pralle has stated, after the discontinuance of return sludge chlorination for a period of ten days, just about ten days with chlorination was required to get the plant back in a satisfactory condition. These results and Mr. Pralle's experiences at Houston strengthen my belief that there is a very tangible "something" to the chlorination of return sludge.

[Since this discussion was presented, a very large and important Eastern plant has been employing return sludge chlorination with beneficial results, even during winter months. Another plant (South) also reports good effects, as measured by visible appearances and a more "even keel" type of plant performance, although there is little in the way of analytical data to reveal just why such is the case. Both plants have started low, raised the chlorine dosage gradually until floc peptization appeared and then dropped the dosage back to a non-wasteful point.—L. H. E.]

For a Splendid Article Dealing With

OPERATION AND CONTROL PRACTICES IN ACTIVATED SLUDGE

By T. R. HASELTINE

See pages 206-209 Reference Section, June, 1942, Issue

ACTIVATED SLUDGE THICKENING

To Improve Digester Performance and Reduce Supernatant Liquor

By D. TRAVAINI

Superintendent, Sewage Treatment Works, Phoenix, Ariz.

PHOENIX, Arizona, has an activated sludge plant with Dorrco aerators, and utilizes separate digestion of mixed crude sludge solids and the wasted activated sludge. C. C. Kennedy, Consulting Engineer, who designed the plant, provided a sludge thickener for the purpose of concentrating activated sludge.

The sludge thickener, as constructed, is a circular tank 35 ft. in diameter with an effective depth of 9 ft. at the periphery of the tank with 1 ft. of free board above the water level. The thickening mechanism was supplied by the Dorr Company and consists of a picket fence made of 2-in. pipe on 6-in. centers extending 5 ft. above the bottom of the tank floor. This is attached to the bracing supporting the bottom scrapers. A skimming arm is also provided.

The tank is centrally located and arranged so that waste activated sludge, mixed liquor, plant effluent, primary sludge, or digester overflow liquor can be admitted through pipe inlets at one side of the tank, approximately 18 ins. below the water level.

The original baffle at the inlet was not satisfactory. Short circuiting was so pronounced that it prevented effective utilization of the tank capacity. After considerable investigation, a Sacramento baffle was installed in May, 1933, and ended the short circuiting troubles. We attribute the successful use of the thickener to this baffle and the installation of a Wallace and Tiernan chlorinator made at the same time, the value of which will be discussed later. Before these improvements were made we were prone to look upon the thickener as a liability rather than an asset.

The Sacramento type baffle was developed under the direction of Professor Charles Gilman Hyde more than ten years ago. The structure built at Phoenix consists of a redwood baffle 24 ins. from the wall at the water surface, tapering to 9 ins. at the wall 36 ins. above the intersection of the vertical wall and sloping bottom. This baffle is perforated with 4-in. square openings on 18-in. centers, both ways. Nine inches in front of these openings are suspended wooden baffle boards 10 ins. wide. (See Sketch.)

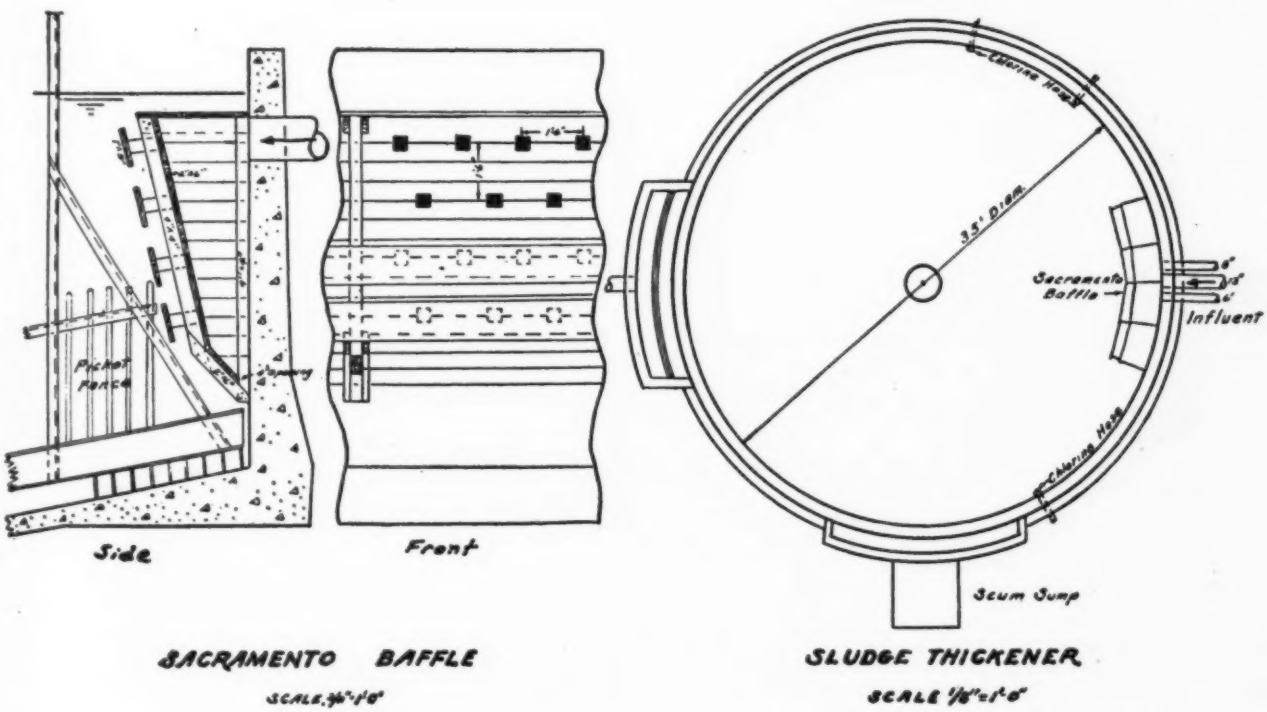
Operation of Thickener

On June 2, 1932, activated sludge had built to a point where wasting could proceed, and the thickener was again placed in service. We were unable, however, to hold the sludge in the thicker sufficiently long to obtain the degree of concentration anticipated when the tank was designed. When we attempted to hold it to increase the solid content to the point anticipated, the sludge would rise and odors became pronounced.

In the early part of October, 1932, we arranged to return plant effluent to the thickener, hoping that the dissolved oxygen in the effluent would retard septic action and thus eliminate odors and allow a longer sludge holding period. This procedure aggravated the short circuiting in the tank and caused the solids in the effluent to increase materially.

The short circuiting in the thickener made it apparent that the original baffle was not efficient and resulted in the installation of the Sacramento baffle. We also installed a Wallace and Tiernan solution feed chlorinator in order to use liquid chlorine to retard septic action. With the chlorinator we anticipated accurate control of chlorine applied to the thickener, which was not possible under the crude conditions in which we had been using lime and chloride of lime earlier.

We devoted our spare time to experiment, to determine the efficiency of the baffle and to find at which points to chlorinate the sludge input in order to obtain the best distribution of chlorine. The results obtained from the baffle were very gratifying. By the trial and error method we selected three points of application of chlorine that gave the best distribution. The chlorine hoses are submerged 3 ft. below the liquid level in the tank. One point of application is 13 ft. along the periphery of the tank from the west end of the baffle. The other two points are 9 ft. and 18 ft., respectively, along the periphery of the tank from the east end of the baffle. (See Sketch.)



Detail of Sacramento Baffle and Plan of Thickener, Showing Location of Baffle and Points of Chlorine Application

TABLE 1—RETURNED SLUDGE AND MIXED-LIQUOR (SLUDGE) THICKENING DATA. (RESULTS REPRESENT 24-HR. COMPOSITE SAMPLING.)

Date	Gals. of mixed liquor wasted	Chlorine #/24 hrs.	Influent (Mixed Liquor)				Effluent				Thickened Sludge	
			pH	% by volume 1 hr. settling	Suspended Solids p.p.m.	Suspended Solids % dry wt.	Total Solids p.p.m.	Suspended Solids p.p.m.	B.O.D. p.p.m.	pH	% Solids dry weight	pH
1/18/34	144000	35	7.6	30	1620	0.162	1075	21	20	7.6	—	—
1/19/34	144000	35	7.6	42	1725	0.172	1007	31	24	7.6	4.021	7.6
1/20/34	132000	35	7.8	50	1823	0.182	1012	31	28	7.8	4.287	7.8
1/21/34	144000	35	7.8	55	1342	0.134	1000	16	38	7.8	3.937	7.8
1/22/34	132000	30	7.6	50	1865	0.186	938	42	36	7.6	3.571	7.8
1/23/34	234000	45	7.6	47	2339	0.234	1020	26	26	7.6	4.120	7.6
1/24/34	288000	53	7.6	42	1618	0.162	1074	37	46	7.6	4.090	7.6
1/25/34	207000	50	7.6	54	2232	0.223	1015	26	32	7.6	3.529	7.6
1/26/34	132000	50	7.6	40	1065	0.106	1045	13	16	7.6	3.996	7.6
1/27/34	172000	41	7.6	32	1255	0.125	909	38	30	7.6	3.827	7.6
1/28/34	158400	40	7.6	30	1863	0.186	1010	27	22	7.6	4.090	7.6
1/29/34	158400	36	7.8	28	1652	0.165	995	13	16	7.8	3.684	7.8

Date	Gals. of returned act. sludge wasted	Chlorine #/24 hrs.	Influent (Returned Activated Sldg.)				Effluent				Thickened Sludge	
			pH	% by volume 1 hr. settling	Suspended Solids p.p.m.	Suspended Solids % dry wt.	Total Solids p.p.m.	Suspended Solids p.p.m.	B.O.D. p.p.m.	pH	% Solids dry weight	pH
2/9/34	70500	60	7.6	98	5243	0.524	1210	36	106	7.6	—	—
2/10/34	60300	65	7.8	88	5651	0.565	1163	43	126	7.8	3.618	7.8
2/11/34	45200	65	7.8	99	6920	0.692	1090	28	95	7.8	3.684	7.8
2/12/34	38500	55	7.8	99	7848	0.785	1215	45	152	7.8	3.242	7.8
2/13/34	54100	65	7.8	98	8132	0.813	1230	52	166	7.8	4.127	7.8
2/14/34	19200	50	8.0	98	7337	0.734	1140	38	120	8.0	4.006	8.0
2/15/34	30300	55	7.8	98	8243	0.824	1125	45	138	7.8	3.529	7.8
2/16/34	11040	40	7.8	98	9130	0.9130	1110	32	95	7.8	3.280	7.8

By varying the quantity of chlorine solution applied at the points mentioned even distribution of chlorine was maintained in the surface liquor, where desired, rather than in the sludge proper.

With this preliminary work completed, during the early summer we tried concentrating primary sludge in combination with mixed liquor taken from the aeration tanks; then primary sludge with returned activated sludge, and then returned activated sludge alone. Very good results were obtained in each instance, but the trials with mixed-liquor seemed the best.

Scheme Giving Best Overall Results

In August, 1933, we decided to try concentrating mixed liquor only, a method suggested by R. F. Goudey.[1]

Our object was, that in summer the primary clarifier influent is stale and we felt that by adding to the crude sewage a sizeable flow of effluent from the thickener, containing dissolved oxygen and some residual chlorine, it would improve plant operating conditions. The amount of thickener effluent would naturally be much greater when concentrating sludge from mixed liquor than when concentrating returned activated sludge and therefore the greater benefit to the crude sewage.

The results obtained by thickening mixed liquor taken from the aeration tanks were so satisfactory that we soon adopted it as routine operation. The primary sludge is concentrated to approximately 5 per cent in the primary clarifier and is mixed with the thickener sludge by pumping sludges from both tanks simultaneously to the digesters.

In Table No. 1 analytical data of thickener operations are given for mixed liquor (above) and for "returned" activated sludge from the clarifier (below). Table 2 shows the solids content of the sludge at various depths. As a result the installation of the Sacramento baffle and chlorination, we can maintain a clear overflow with the sludge blanket within 3 ft. of the liquid level, when wasting 200 gpm. or less of mixed liquor or returned sludge through the thickener. The cost of chlorination is considered very nominal considering its advantages.

[1]"A New Method of Concentrating Activated Sludge," R. F. Goudey and S. M. Bennett. WATERWORKS AND SEWERAGE, May, 1933.

TABLE 2—SLUDGE CONCENTRATION DATA

	Depth from liquid level in ft.	Nov 3 1933	Dec. 11 1933	Jan 20 1934	Feb 11 1934
% Solids in sludge at depth shown	3	—	0.25	0.27	0.810
	4	0.60	0.50	0.70	1.02
	5	1.20	1.05	1.45	1.35
	6	1.04	1.25	1.37	1.72
	7	1.20	1.40	1.55	2.38
	8	1.40	1.70	2.10	2.87
	9	3.50	3.25	3.75	3.05
	Cone	4.08	4.21	4.28	3.68

Conclusions

Since we installed the Sacramento baffle and eliminated short circuiting, and since we started to chlorinate the top liquor to retard bacterial action and thereby control septicity, the thickener has operated satisfactorily and accomplishes the purpose for which it was designed, viz.: reducing the volume of sludge and hense the volume of supernatant liquor which is so disastrous to the activated sludge process. Likewise the need for greater digester capacity.

[NOTE—This scheme of sludge concentration has since been adopted at other activated sludge plants—notably Lancaster, Topeka, Baltimore, New York City.—Ed.]

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GRAVER SEWAGE EQUIPMENT

Aerators — Agitators — Automatic Dosing Siphons — Chemical Feeders — Chemical Proportioners — Chemical Treatment Plants — Coagulators — Clarifiers, Primary and Secondary — Digesters — Grease Removal Equipment — Gas Holders — Imhoff Combination Clarifiers — Reactivator Clarifiers — Rotary Distributors — Skimmers — Sludge Conditioners — Sludge Dryers — Sludge Filters

GRAVER ROTARY DISTRIBUTORS

Graver Rotary Distributors are built for all applications of high and low rate trickling filters. The sewage is uniformly sprayed over the rock bed, and the reaction of the discharge propels the mechanism. The center columns are made with either mercury seals, having automatic mercury return in case of blow-outs, or with mechanical seals. The trickling filter effluent may be recirculated if necessary.

Graver Standard Rotary Distributors operate either from an automatic dosing siphon or from a pump. Proper discharge is obtained under a head as low as 6″ at the distributor center column. On the other hand, the head may rise as high as may be required by existing conditions, and the discharge through the distributor arms is still perfectly regular.

Nozzles provide wide, thin spray for proper distribution and aeration. The spray width is adjustable and the nozzles are designed to be fully accessible for ease in cleaning without losing their adjustment.

GRAVER DIGESTER EQUIPMENT

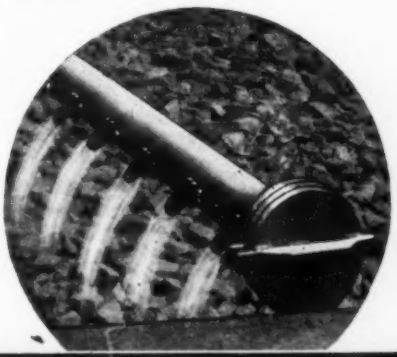
Graver offers a complete line of digester mechanisms and covers which have proven their value in more than ten years of operation. Graver Floating Digester Covers are floated by the gases accumulating under the dome. Agitators can be installed to disperse and submerge scum and promote seeding and inoculation of fresh sludge. Safety features include flame traps and pressure and vacuum relief valves. The equipment is designed so that it is impossible to generate an explosive mixture of gases.

GRAVER REACTIVATOR CLARIFIERS

This equipment is designed to provide high turbidity removal and is ideal for use in primary sewage plants to provide primary treatment or to bring existing overloaded plants back to capacity. With this system, chemicals are mixed with raw sewage, precipitated sludge is recirculated, and the mixture is passed through a suspended sludge bed, insuring intimate contact and complete sludge filtration. Integral aeration is provided to prevent septic action and all steps are carried out in a single tank.

Graver also manufactures a complete line of Primary and Secondary Clarifiers for quiescent clarification in circular settling tanks of small and large diameters. Noteworthy among these is the Graver "Flexidrive" Clarifier which includes such special features as Automatic Scum Trap and Trackless Drive Bridge.

Gravr engineers will gladly discuss your sewage treatment problems with you and cooperate with your engineers in the design of equipment to meet your requirements.

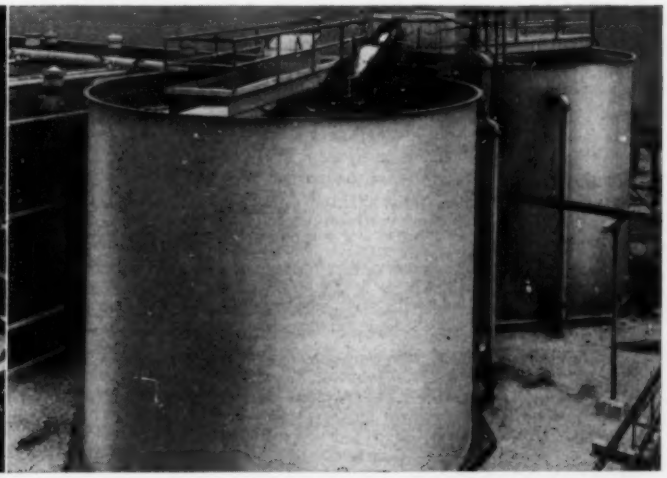


Right—Close-up of Graver Distributor Nozzles.

Below — Installation of Graver Digester Equipment.

Above—Graver Rotary Distributor installation.

Below—Graver Reactivator Clarifiers.



See Our Advertisement on Water Conditioning Equipment, Page 137

SLUDGE DIGESTION TEMPERATURE CONTROL WITH LIVE STEAM

By A. M. RAWN*

Chief Engineer and General Manager, County Sanitation Districts of Los Angeles County, Los Angeles, Calif.

THE accelerated rate of sewage sludge digestion at temperatures ranging from 85 to 95 degrees Fahrenheit necessitates the application of external heat to the digesting sludge mass. Currently, in most plants the heat is applied by circulating water of a given temperature through metal coils appropriately located on the interior walls of digestion tanks, or suspended in the sludge itself. The water may be jacket water from gas engines or constantly recirculated water heated in boilers of required capacity. Circulation is usually accomplished by pumping.

If fuel is at a premium, as, for instance, if power is generated from sludge gas at the treatment works and the entire gas supply is conserved for power generation, circulation of the gas engine jacket water presents definite advantages, and the difficulties attendant upon circulation of hot water through coils in the sludge mass is entirely warranted; but if there is a moderate excess of fuel which cannot otherwise be utilized in the operation of the plant or its features, it appears that there is another and better way of adjusting sludge temperatures.

Disadvantages of Coil Heating

Some of the disadvantages attendant upon heating sludge with circulating hot water in coils are:

1. Cost of the coils.
2. Cost of the pumping circulating water.
3. Removal of scale from exterior of coils as well as at times the interior.
4. Inflexibility of the operation, that is, the inability to heat sludge at any place but in tanks built and equipped specifically for that purpose, or to compensate for the difference between winter and summer sludge temperatures.
5. The periodic dosing of cold sludge into warm sludge mass.
6. Galvanic corrosion causing coil hangers to fail, allowing the coils to sag and leak or drop down.

Beginning in 1930 and up until last March, practice at the Joint Dispoal Plant of the Los Angeles County Sanitation Districts has been to heat digesting sludge by circulating hot water through cast iron pipe coils attached to the walls of the multi-stage sludge digestion tanks. While the process has been successful, it has exhibited all of the shortcomings hereinbefore noted but No. 6, which has occurred elsewhere. The most annoying deficiency has been the incrustation on (and within) the pipe coils, necessitating progressively higher water temperatures with correspondingly accelerated incrustations, ad infinitum, and the inability to maintain proper temperatures in the digesting mass throughout the year because of wide temperature range in the raw sludge from winter to summer.

Use of Live Steam for Direct Heating

Three or four years ago experiments were commenced at the plant looking toward the possible use of live steam for sludge heating. The experiments were moderate in scale and were aimed principally at ascertaining whether or not live steam would, through partial sterilization of the input of crude and seeding sludge, retard digestion. The information gained from this work was so conclusive as to the advantages of the method that a decision was made to use live steam in sludge heating when it became necessary to expand the sludge digestion facilities at the plant.

Construction of a third battery of multi-stage sludge digestion tanks was commenced as a WPA project in the summer of 1940, but with difficulties attendant upon the current crisis in national affairs and the present emergency, the battery was not completed and placed into operation until March, 1942. By the time the tanks were completed, the remaining sludge digestion features at the plant had reached saturation and every spare tank in the area of any description was filled with digesting sludge. Unfortunately, however, only the two 1930 batteries could be heated, consequently sludge digestion in the remainder of the unused tanks and basins in and about the plant area was greatly retarded because of lack of temperature control.

*Editorial Associate, Water Works and Sewerage.

With the advent of March the situation was acute, but by that time the new battery of sludge digestion tanks was completed, including the 70 hp. boiler installation (see picture) designed to utilize sludge gas for fuel and to provide steam for heating sludge at the suction pumps of the two raw sludge concentrating wells.

The picture changed immediately. Sludge in the temporary tanks, in which the temperatures approximated 70 degrees, was recirculated through the crude sludge concentration tanks along with raw solids and raised to a temperature of 90 to 95 degrees at the transfer pump suction, then returned to the tanks, or transferred to other digesting units. The newly completed battery was filled with sludge and seed which had been raised to a temperature of 90 degrees F. and which maintained temperatures of 85 to 90 degrees without further heating until digested. A large partially digested sludge mass in the holding pit was warmed and construction immediately commenced upon covering certain unused sedimentation tanks in the plant with temporary gas tight covers of timber and roofing construction. These fixed covers converted these tanks into useful digestion units—a feature which could not have been accomplished otherwise without great cost for heating coils. One trio of these tanks, illustrated here, has been completed and is functioning with complete success.

The Districts' Joint Disposal Plant was originally constructed as an activated sludge sewage treatment works and functioned in that capacity from 1928 to 1938. Upon completion of the ocean outfall, the activated sludge features were removed from the plant and it was converted into a primary sedimentation works with separate sludge digestion. Looking to the day of an ocean outfall, the former aeration tanks (twenty-two in number) had been designed primarily for use as plain subsidence tanks, and eight of them were immediately equipped with sludge removal mechanisms. The fourteen remaining tanks will be equipped in a similar manner as increased flows at the works require their use, but in the meantime they are idle and it is a trio of these tanks—each 12½x12½ feet in section and 175 feet in length—which have been converted into sludge digestion units. Three more sets of tanks will be similarly equipped this summer.

Plant Practice

Present practice at the plant is to transfer raw sludge from eight sedimentation basins to two sludge concentration tanks. Sedimentation basins are 12½x12½ feet in section and 175 feet long. Sludge concentration tanks are of like cross section but are 50 feet in length and lie side by side, their long axes parallel. Each concentration tank is equipped to drain to a small

70-HP. Boiler Used to Supply Steam for Direct Heating of Mixed Sludge Input to Coil-less Digesters—Formerly Sedimentation Tanks

bottom hopper from which the sludge transfer pump suction draws. As the concentration tanks are being filled with raw sludge, 20 per cent by volume of digested sludge is returned thereto for "seed." When the tanks have been filled with the mixture, the entire mass is transferred to the designated sludge digestion tank, and as the transfer pump starts, live steam is ejected into the tank hopper from which sludge is drawn.

Advantages of the System

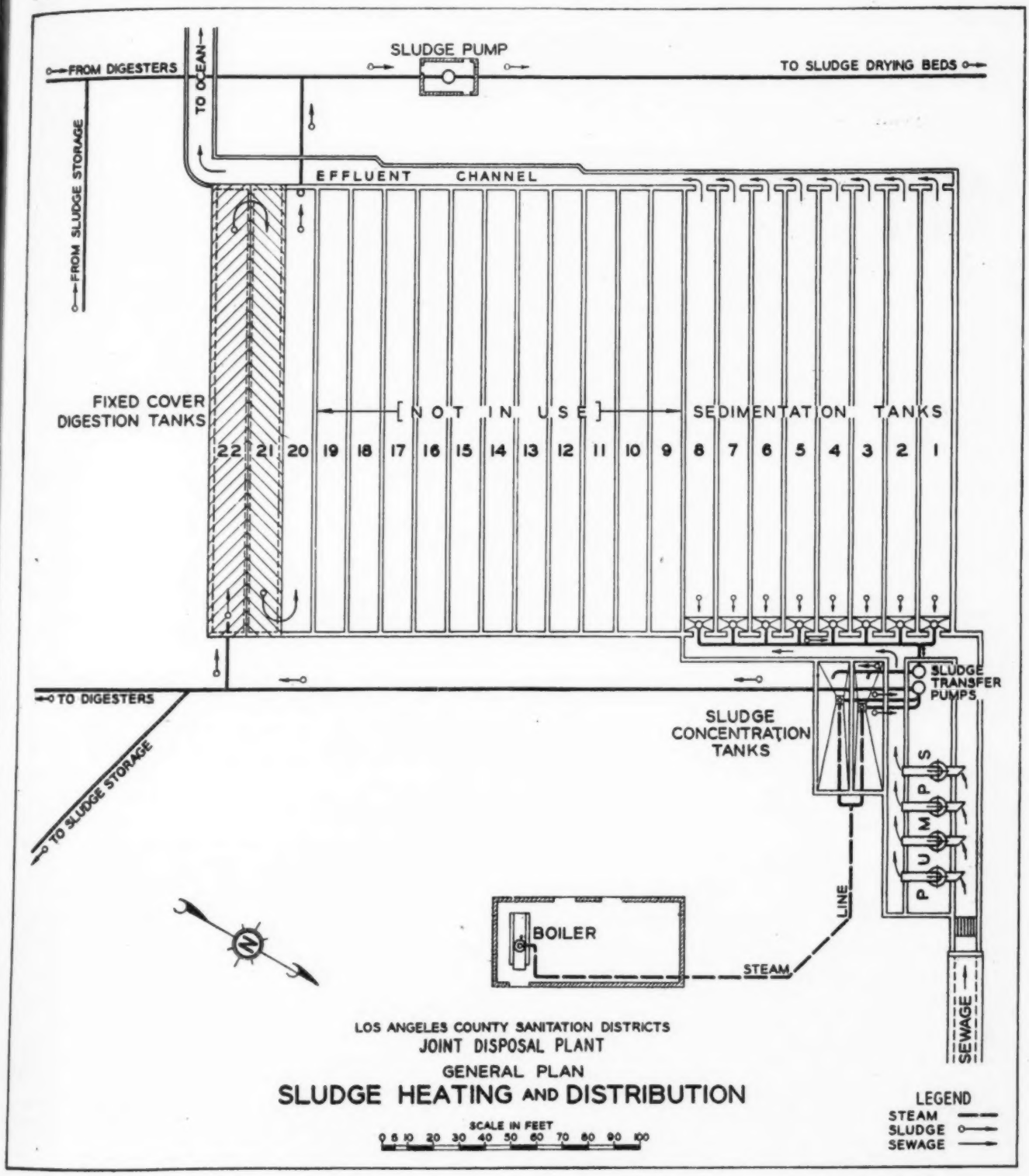
The system has many advantages:

1. It is entirely flexible, permitting the control of sludge temperature in any receptacle which will hold sludge, whether it be an earthen pit, a lined retention chamber—covered or uncovered—an unused tank or basin, or a regulation sludge digestion unit.

2. The adjustment of sludge temperature is not at all dependent upon the temperature of the incoming sludge. The adjustment is made by either regulating the flow of steam at the pump suction or the speed of the transfer pump.

3. It eliminates entirely the use of heating coils with all of their attendant difficulties.

4. It permits a 10 degree F. rise in temperature in more than 100 gallons of wet sludge, with but one gallon of water applied as steam, thus less than 1 per cent is added to the sludge mass as water.



General Plan of Sludge Heating with Live Steam and Its Distribution—Los Angeles County Joint Disposal Plant.

5. It admits of dosing warmed sludge into the warm sludge mass whereby the temperature of the digesting sludge is not disturbed or changed during the process of dosing.

6. The heating and transfer of sludge from the concentration tanks to the digestion tanks—or whatever structures in the area are being used for that purpose at the time, is accomplished in about four hours daily. The total amount of raw sludge transferred to digestion every day approximates 175,000 gallons, to which is added 45,000 gallons of seed before the sludge is warmed up. Said sludge usually drawn from the multi-stage digestion tanks—but occasionally from tthe sludge concentration pit—and the mixing of raw and seed sludges prior to transfer to a digestion chamber, results in a lessened disturbance of seed to raw sludge ratio in any of the tanks in which the mass is discharged.

The foregoing are about the main advantages of this new adventure. It has the disadvantage of using more water than the water circulation system, and it likewise does not take advantage of heat transferred to the jacket water of sludge gas engines, although even this may eventually be possible when the new "Vapor-Phase" cooling system is perfected, wherein the circulating water is constantly maintained above the boiling point and live steam given off as the pressure is released in recirculation.

Question of Odors

Lest there be some misgivings about odors emanating from raw sludge heated to temperatures of from 85 to 95 degrees F., it is worthy of note that the contents of the sludge concentration tanks have been raised to a temperature of 130 degrees F. without any noticeable or distinguishable change in the odor of the contents, and since there has been some question regarding vapor-lock in a sludge pump when live steam is injected into the suction line within 20 feet or so of the pump itself, it may be stated that the experience at the District's disposal plant indicates that the sludge pumps operate as smoothly with the steam injected into the suction as without.

The steam boiler at the Sanitation District's disposal plant is operated at a pressure of 30 pounds per square inch. The only advantage in this over a much lower pressure is that the steam feed water pump will not operate at less tthan 30 pounds; otherwise the pressure would be maintained at below 15 pounds. Because of the latent heat factor in live steam, the gallons of sludge which may be heated by one gallon of water converted to steam at zero pressure is almost equal to the amount which may be converted at 125 pounds per square inch, the difference being in the ratio of approximately 110 to 114. This approximate computation is based upon the use of saturated steam and an assumed heat capacity of sludge of 1 B.t.u. per pound per degree Fahrenheit.

Use of Non-Critical Materials and Simplicity a Feature

The process is so easily installed, so cheaply operated, and so extremely flexible, and has proven so successful in operation at the plant described, that the information is passed on for the benefit of those who may encounter some of the difficulties herein enumerated with the present system of heat transmission. It also is detailed here to some extent to indicate that in this paricular time of shortage of materials and restrictions upon the use of available materials by WPB and other Federal agencies, existing tanks or basins in or about the plant not otherwise in use may be covered with inexpensive tops of some sort comprised of materials which are not deemed critical at this time, and converted directly into controlled sludge digestion tanks for use during the emergency. The potentialities of the system become apparent when one visualizes its complete flexibility. The fact that it has no deleterious effect upon sludge digestion is a strong argument in its favor.

CLEANING ENCRUSTED PIPE LINES AND VACUUM FILTERS WITH INHIBITED MURIATIC ACID

By K. L. MICK
Chief Chemist
Minneapolis-Saint Paul Sanitary District
St. Paul, Minnesota

CONSIDERABLE muriatic or hydrochloric acid has been used in our plant for removing carbonate scale from pipe lines, filter cloths and vacuum filter parts. To minimize the acid attack on metal parts of the equipment and on pipe lines, it was deemed advisable to use an inhibitor with the acid. Certain protein materials such as bran, or organic amino compounds such as aniline oil (aminobenzene, $C_6H_5NH_2$) are capable of retarding the action of strong acids on metals by preventing or slowing down the evolution of hydrogen at the metal surface in the reaction—

$$Fe + 2HCl = FeCl_2 + H_2\uparrow \text{ (gas)}$$

They are called inhibitors and are believed to function by raising the hydrogen overvoltage on the metal, i.e., they raise the potential required to force off the protective blanket of hydrogen as gas bubbles. Unless sufficient potential is available, the hydrogen will tend to accumulate on the metal surface and the reaction written above will slow down or stop, thus protecting the metal from further action of the acid. However, the corrosion inhibitor will not affect the action of acid on the carbonate scale which it is desired to remove, the reaction being—

$$CaCO_3 + 2HCl = CaCl_2 + Co_2\uparrow + H_2O$$

Twin-Cities Plant Practice

The acid used at this plant is commercial 18° Bé. muriatic acid (28 per cent HCl), purchased in 125 pound carboys. Some laboratory tests were made to determine the proper proportion of aniline oil to acid. For these tests a number of 1x3 inch panels of 23 gauge mild steel were immersed in acid solutions of various strengths, 0.7 per cent HCl, 2 per cent, 5 per cent and 10 per cent. One of each of these acid solutions was left untreated with the aniline oil to serve as a control comparison, and aniline oil was then added in various dosages to each of the acid solutions. In evaluating the rates of acid corrosion of the steel, use was made of Speller's formula, which takes into account the loss in weight, the area exposed, and the time of exposure.

The results indicated that a 2 per cent aniline oil dosage (by a weight of pure HCl) could be used with the weaker acid solutions, up through 5 per cent HCl, while stronger acid solutions should have a 3 or 4 per cent aniline oil dosage for maximum protection of metal parts.

With a 0.7 per cent HCl solution (which is the initial strength obtained in our plant when one carboy of commercial muriatic acid is added to about 600 gallons of water in the filter pan), a 2 per cent aniline oil dosage will cut the corrosiveness of the acid by 44 per cent, according to the laboratory tests. A 2 per cent aniline oil dosage in a 5 per cent HCl solution cuts the rate of corrosion nearly 97 per cent, while in a 10 per cent HCl solution a 4 per cent aniline oil dosage was required to reduce the rate of corrosion by 69 per cent.

Added to a one-carboy acid bath for a filter, 300 ml. of aniline oil will reduce the corrosiveness of the acid about 44 per cent for the small cost of 25 cents. For protection of the screen and the thin nailheads in the wood splines, this added precaution would seem justified even though the rate of corrosion with an acid solution of this strength is apparently quite low.

The application of the acid bath is very simple. Sufficient water is run into the filter pan to just submerge a portion of the drum (about 600 gallons at this plant). The aniline oil treated carboy of acid is then syphoned into the water, with the filter drum and agitator in operation. After two or three hours the acid is usually pretty well spent (a titration test will tell) and the solution is then drained off and the filter washed with the water sprays. If the filter and cloth are badly scaled, more than one carboy of acid may be needed.

The filters at this plant are now given an acid bath after about 350 hours of cloth life, with the cloth and screen left in place. This treatment increases the economical life of the filter cloth to 500 or 600 hours and at the same time removes the scale from the screen and splines.

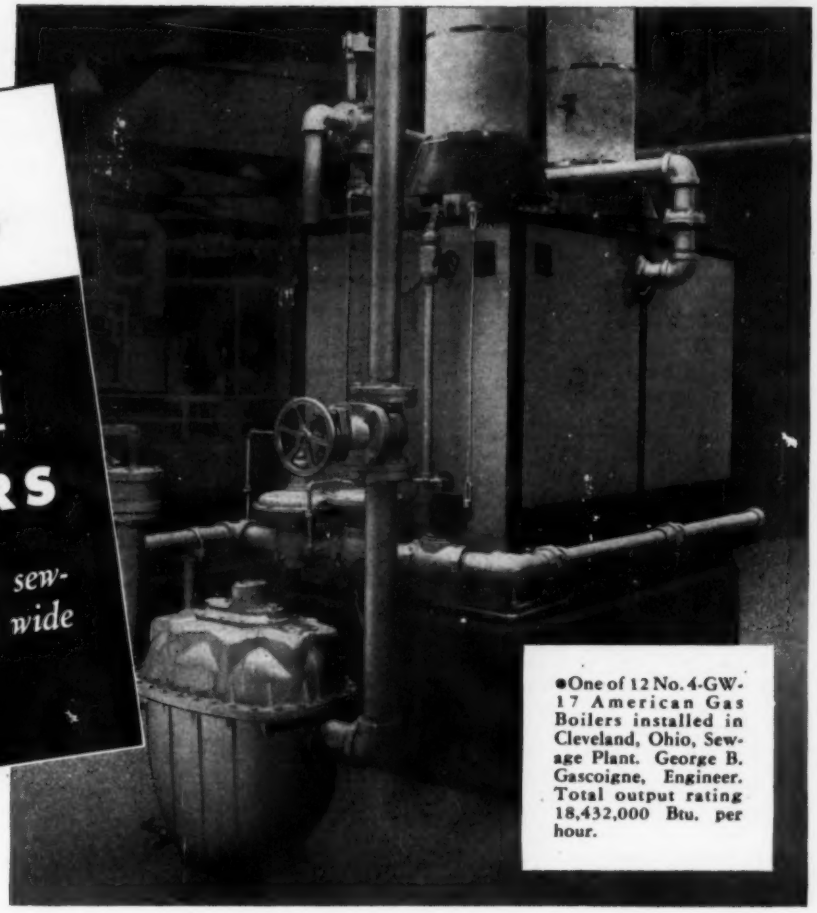
To clean the pipe lines of carbonate scale, the inhibited acid bath is recirculated through the lines. The scale is disintegrated and sloughs off.

[Ed. Note—It is quite evident that the use of inhibited acid applies in water purification plants as well as sewage plants—also for cleaning small pipe lines of iron scale.]

FOR HEATING
SLUDGE DIGESTERS

AMERICAN
GAS BOILERS

correctly designed to burn sewage gas—by engineers with wide field experience.



●One of 12 No. 4-GW-17 American Gas Boilers installed in Cleveland, Ohio, Sewage Plant. George B. Gascoigne, Engineer. Total output rating 18,432,000 Btu. per hour.

Many hundreds now installed from Coast to Coast

Based on the experience of users, you cannot go wrong in specifying AMERICAN Gas Boilers for heating your sludge digesters.

These boilers are engineered for dependable, trouble-free operation and especially qualified for burning sewage gas. They are completely automatic, one valve controlling water temperature to any predetermined degree. Patented pintype sections afford the most effective type of cast iron heat absorbing surface. Controls are available to accommodate any desired system of gas, temperature or pressure regulation. A wide range of sizes meets all requirements. Detailed information on request.

Note: AMERICAN Gas-Fired Storage Water Heaters, for supplying hot water for necessary needs, are temporarily not available, due to WPB Limitations.

AMERICAN RADIATOR & Standard Sanitary
New York CORPORATION Pittsburgh

AMERICAN GAS BOILER CAPACITIES WITH SEWAGE DISPOSAL GAS

BOILER NO.		OUTPUT PER HOUR			INPUT PER HR.		BOILER SPACE		
								Floor Space	
Steam	Water	BTU. per Hour	Sq. Ft. Steam A.G.A. Rating	Sq. Ft. Water A.G.A. Rating	BTU. per Hour	Cu. Ft. 700 BTU. Sludge Gas	Over-all Hght.	Width Front	Depth
.....	1-GA-4	31,500	.....	210	39,350	56	40 ½"	14 ½"	22 ½"
.....	1-GA-5	42,000	.....	280	52,500	75	40 ½	14 ½	25 ½
.....	1-GA-6	52,500	.....	350	65,600	94	40 ½	14 ½	28 ½
.....	2-GA-4	63,000	.....	420	78,750	113	45 ¾	19 ½	22 ½
.....	2-GA-5	84,000	.....	560	105,000	150	45 ¾	19 ½	25 ½
.....	2-GA-6	105,000	.....	700	131,200	188	45 ¾	19 ½	28 ½
.....	2-GA-7	126,000	.....	840	157,500	225	45 ¾	19 ½	31 ½
.....	4-GA-9	168,000	.....	1120	210,000	300	45 ¾	28	38
.....	4-GA-11	210,000	.....	1400	262,500	375	45 ¾	28	44
.....	4-GA-13	252,000	.....	1680	315,000	450	45 ¾	28	50
0-GS-4E	.....	61,200	255	.....	76,600	109	40 ½	16	33 ¾
0-GS-5E	.....	81,600	340	.....	102,000	146	40 ½	16	37 ¾
0-GS-6E	.....	102,000	425	.....	127,500	182	40 ½	16	41 ¾
0-GS-7E	.....	122,000	510	.....	153,000	218	40 ½	16	45
1-GS-4	1-GW-4	146,000	610	980	182,500	261	54 ½	35*	33 ¾
1-GS-5	1-GW-5	186,000	775	1240	232,500	332	56 ¾	39*	33 ¾
1-GS-6	1-GW-6	225,000	940	1500	281,500	402	56 ½	43*	33 ¾
1-GS-7	1-GW-7	265,000	1105	1770	331,000	473	57	47*	33 ¾
1-GS-8	1-GW-8	305,000	1270	2030	381,000	545	59 ¼	51*	33 ¾
1-GS-9	1-GW-9	345,000	1435	2300	431,000	616	58 ½	55*	33 ¾
1-GS-10	1-GW-10	384,000	1600	2560	480,000	686	59 ¾	59*	33 ¾
1-GS-11	1-GW-11	424,000	1765	2820	530,000	757	59	63*	33 ¾
4-GS-6	4-GW-6	480,000	2000	3200	600,000	857	69	53	52
4-GS-7	4-GW-7	576,000	2400	3840	722,000	1030	69 ¾	58	52
4-GS-8	4-GW-8	672,000	2800	4480	840,000	1200	71 ¾	62	52
4-GS-9	4-GW-9	768,000	3200	5120	960,000	1372	72 ½	66	52
4-GS-10	4-GW-10	864,000	3600	5760	1,079,000	1543	75	70	52
4-GS-11	4-GW-11	960,000	4000	6400	1,200,000	1715	75 ¾	74	52
4-GS-13	4-GW-13	1,152,000	4800	7680	1,440,000	2060	69 ¾	85	64
4-GS-15	4-GW-15	1,344,000	5600	8960	1,680,000	2400	71 ¾	93	64
4-GS-17	4-GW-17	1,536,000	6400	10240	1,920,000	2740	72 ½	103	64
4-GS-19	4-GW-19	1,728,000	7200	11520	2,162,000	3090	75	107	64
4-GS-21	4-GW-21	1,920,000	8000	12800	2,400,000	3425	75 ¾	110	64
4-GS-22	4-GW-22	2,016,000	8400	13440	2,520,000	3600	71 ¾	136	64
4-GS-25	4-GW-25	2,304,000	9600	15360	2,880,000	4120	72 ½	148	64
4-GS-28	4-GW-28	2,592,000	10800	17280	3,240,000	4625	75	160	64
4-GS-31	4-GW-31	2,880,000	12000	19200	3,600,000	5145	75 ¾	172	64
4-GS-33	4-GW-33	3,072,000	12800	20480	3,840,000	5480	72 ½	186	64
4-GS-37	4-GW-37	3,456,000	14400	23040	4,320,000	6165	75	202	64
4-GS-41	4-GW-41	3,840,000	16000	25600	4,800,000	6850	75 ¾	218	64

*1-GS shown. The 1-GW is 4" shorter

CORROSION OF SLUDGE DIGESTER PARTS

Corrected by Application of Cathodic Protection

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AFTER fourteen months of service it was a decided shock to find that the metal parts within the sludge digestion tanks of the Terminal Island Treatment Works of Los Angeles had suffered marked corrosion. Almost every metal part that had been in contact with sludge, scum or supernatent liquor had suffered attack. Pitting had penetrated to a depth of five-sixteenths of an inch in a few places, while in many places extensive areas showed corrosion varying from one thirty-second to one-eighth of an inch below the original surface.

Certain peculiarities were noticed. One side of a structural member might be severely corroded while the other side of the same member remained entirely untouched. The hot water coils of galvanized wrought iron were badly attacked in some places and in others the original galvanizing was intact. The hooks supporting the coils were likewise affected.

No one part of the tank was affected more than another and all metal parts in the tank were affected. It so happened that all these parts were of iron or steel and no brass, aluminum or other non-ferrous metals were present. Interestingly, the galvanized wrought iron pipe had been attacked as badly as the structural steel of the sludge stirring mechanism. The digester in question is a single stage, fixed cover, heated, concrete tank, 75 feet in diameter by 27 feet sidewall height.

The sewage treated at the Terminal Island plant averages about 3.0 million gallons daily and includes a considerable industrial load from two fish canneries. Solids and oil in the cannery waste caused a thick tenacious scum to form in the digester.

What the Inspection Revealed

To examine conditions, it was decided to shut the plant down and drain the digester and make a thorough inspection.

On entering the tank for inspection, while it was being drained, the writer felt several manhole steps bend under his feet. Later, it was found that these steps, originally ¾ inch in diameter, were eaten nearly through. On the other hand, it was of peculiar interest that some of the steps were as good as new.

The sludge was transferred to the clarifier and decantation tanks for storage. This saving of sludge proved to be a fortunate thing, for it not only provided a sufficiency of seed sludge when the digester was again placed in operation, but it also supplied the real clue which led to the final solution of the corrosion problem at Terminal Island.

As soon as the tank was clean, and safe to enter without wearing hose masks, the surprising conditions were discovered. Out of all the mass of facts observed and noted only two observations seemed to be favorable. There was no indication that the concrete of the tank itself was damaged, nor was there any evidence that the steel reinforcement embedded in the concrete had been attacked.

This last fact was a good deal of a puzzle, but at the same time it was a Godsend, for if the reinforcement had been corroded, the concrete would have been cracked beyond repair and the whole tank a total loss. The effects of the corrosion were so serious and had taken place in so short a time, that it was evident that unless the cause were discovered and eliminated, the entire mechanism and perhaps also the tank would soon be destroyed.

Causes Considered

Several theories were advanced as to the cause of the corrosion, none of which proved of any help in the solution of the problem. Inquiries at the time failed to reveal any similar conditions elsewhere, although some cases of corrosion in digesters have been reported more recently.

The sludge was not altogether normal, due to the presence of the fish waste already mentioned, although the pH had been consistently above 7.0. This fact seemed to eliminate the possibility of acid corrosion.

Later investigation showed that the sludge and scum were high in either sludge matter, probably high in sulphides and extremely high in chlorides. The latter, which was due to large quantities of sea water and brine used by the fish canneries, has sometimes amounted to 2,000 ppm. in the raw sewage entering the plant during the sardine packing season and for some unknown reason is concentrated to as high as 5,000 ppm. in the sludge in the digester. These figures vary widely, the average being less than one-half the above. These facts, particularly the chlorides, undoubtedly had a bearing on the case, but were not known at the time the corrosion was discovered.

In the meantime, while the theorizing was going on, reconstruction work was under way in the digester under the direction of the writer. The original scum breaker was removed and a short, stiff truss was installed with vertical angles which meshed with stationary combs bolted to the roof. Figures I and II show some stages of this work. The hooks, which supported the hot water coils, being no longer safe, a system of wooden racks of redwood lumber was devised by the writer. These racks were held together by birch dowels, as wood is known to be very resistant to digestion processes. Part of these wooden pipe racks can be seen in Figure II.

The Investigations

The suggestion was finally made that the corrosion was similar to that caused by galvanic action or by electrolysis, the last being usually caused by stray electric currents. As this theory seemed to be more reasonable than most of those advanced, investigations were undertaken to find the source of such currents. These studies were made while the repairs were going on.

Alternating current is used for lighting the plant and for power to operate the digester mechanism, but all previous research has shown that alternating current is rarely, if ever, a cause of electrolytic corrosion to any serious degree.

A well known expert on electrolysis inspected the plant and gave the opinion that the corrosion was caused by stray direct currents from street railway operation. It was found, however, that there are no electric railways on the island and that there is no direct current produced or used in any appreciable amount. Furthermore, the only possible path by which such current could enter the plant was by the city water main. The water service pipe was disconnected and it was found that a higher electrical potential existed in the plant system than in the water main, indicating that the source of current was *inside* the plant rather than outside of it. This proved an important discovery.

At this time, the services of Mr. Otto Wiemer, Electrical Engineer of the Department of Building & Safety, of the city of Los Angeles, were obtained, who, with the writer, made an extensive series of investigations as to the source of the electric current which was apparently being generated within the plant.

A complete description of all the investigations would be far too lengthy to be included in this article. Many experiments and unsuccessful attempts were made to correlate the electrical potentials which were found to exist between the different parts of the plant. Various types of grounds were used, chromium rods, copper sulphate sponges, and what not. But the chief difficulty was the inability, with these methods, to reproduce any observed reading on two successive days.

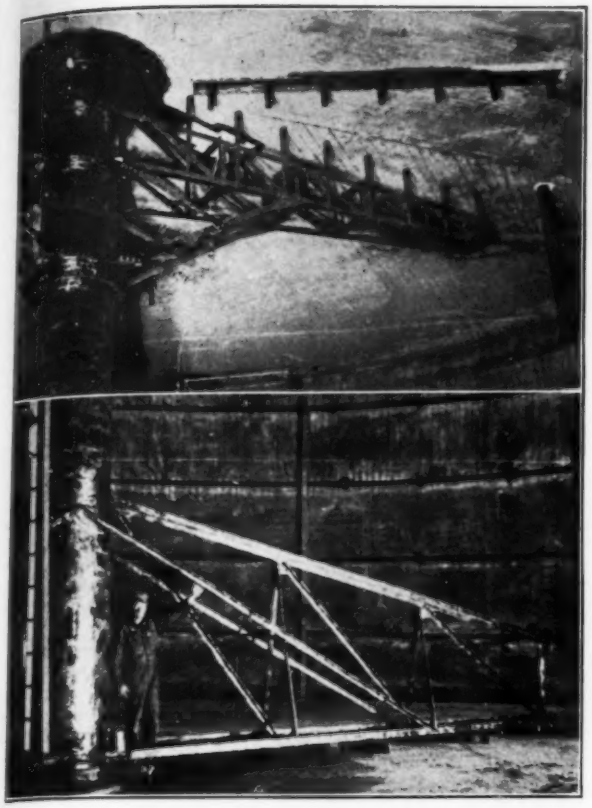
The "Bench-Mark" Method

Finally a method was decided upon, which for want of a better name was called the "bench-mark" method. This simply consisted of using one point (a conveniently situated water faucet), as a reference point and observing the potentials—i. e., voltages, of all other points in the plant, with reference to this one point. Several hundred readings were made and recorded showing values, positive or negative, with reference to our "bench-mark." It was found that these readings could nearly always be checked quite closely when the work was repeated on subsequent days.

The equipment used for this work consisted of a very sensitive voltammeter, known as a Rawson Junior "Multi-meter," with full scale readings in decade arrangements from as low as two millivolts to one thousand volts and from 0.1 milliampere to one ampere. Several hundred feet of No. 12 rubber-covered wire on a spool, and numerous clips and points for making connections, completed the outfit.

The Clarifier Proves a Giant Galvanic Cell

It has already been stated that during the reconstruction of the digester, the plant had been shut down and the contents of the



Figs. I and II—Digester Interior

Showing mechanism protected with Bitumastic coating, which reduces current requirement and enhances efficiency in Cathodic protection. (Above)—New scum-breaker, with stationary combs bolted to roof. (Below)—Sludge-sweep mechanism and heating coils on tank walls, both protected with "Bitumastic" enamel.

digester transferred to the clarifier and decantation tanks for storage.

It so happened that most of the first readings were made at scattered points throughout the plant and showed only small voltages above or below the "bench-mark." However, finally, a series of increasing potentials noted led to the clarifier, in which digested sludge was stored. Here a difference of four hundred millivolts (0.4 volts) was found between various parts of the clarifier piping and steel work and our "bench-mark." Similar but lower differences existed between parts of the decantation tanks (also filled with sludge) and the "bench-mark."

The investigation was continued and readings made of differences of potential between the "bench-mark" and several hundred points throughout the plant. These points included hot and cold water systems, sludge pipes, electrical conduits, exposed metal parts in tanks, reinforcing steel in various structures and even hand rails and the wire fence enclosing the plant property.

The readings varied over a wide range, positive or negative, to the "bench-mark." But, from a study of all the readings, it became evident that greatest differences of potential existed between the point of reference and those tanks in which the digesting sludge was stored.

Figure III—A table which appears later—reveals the method of keeping the notes.

The only possible inference which could be drawn from these observations was that in some manner, not entirely clear, the said tanks were acting as huge galvanic wet cells and were actually producing direct current. This current was leaking out through many inter-connected paths throughout the plant and was returning through other paths to complete the electrical circuit.

In applying this "wet battery" theory to the digester, which was still undergoing repairs, it was possible to conceive that the corrosion already described could ahve been caused in this way, provided the corroded parts were "anodic" (positive), and some other parts were "cathodic,"—i. e., negative. In galvanic action, current flow is always from the positive to the negative electrode.

It is well known that when two dissimilar metals are immersed in an electrolyte and connected externally, a current will flow from one electrode to the other and that one of the electrodes (the anode) will pass into ionic solution in the process. Such action is known as galvanic action. It is also well known that it is not necessary to have entirely dissimilar metals, such as copper and zinc, for such a condition to exist. Even electrodes of the same material, such as iron, which by reason of difference in area, or surface condition or partial protection, will behave in the same manner and one of the electrodes will be eaten away.

Laboratory and Model Studies

A number of tests made in the laboratory, using numerous samples of iron and steel, and sludge liquor for electrolyte, proved that electrolytic corrosion could take place. One test was made with two small grids of black iron bailing wire of exactly the same size and shape. One grid was used bare and the other was cast in a plaque of concrete, one inch thick. Both grids were immersed in sludge liquor and showed a definite flow of current when externally connected. Diagram No. 1 shows the well known principle of the galvanic cell and the close relation to our sludge cell, which behaved in a similar manner.

FIG. III—TYPICAL NOTES OF POTENTIAL DIFFERENCES USING THE "BENCH-MARK" METHOD

Location	Potential* Millivolts
6-in. C. I. pipe to east sludge beds	+ 21
2-in. W. I. pipe—sprinkler system	+ 3
Reinforcing steel—digester wall	+ 36
Wire fence—south property line	— 13
Telephone conduit—office	+ 18
Hand rail—pump house	+ 42
Discharge—high pressure wash pump	+150
4-in. C. I. suction—effluent wash at clarifier	+400**
Clarifier sludge outlet pipe	+385**
4-in. C. I. gas pipe at regulator pit	+ 32
Decanter tank—sample pipe	+108**
Decanter tank—float guide	+210**
Gas holder frame	+ 32
Digester—supernatant overflow pipe at ground line	+ 18
Reinforcing steel—venturi flume structure	+ 11

*Potential expressed in millivolts between the water-faucet "bench-mark" and the equipment listed, + meaning flow away from the unit listed.

**Digester sludge was stored in these tanks.

A model was then constructed to simulate, in principle, the construction of the digester. The model was made of concrete, sixteen inches in diameter and twelve inches high, with walls and bottom two inches thick. A cage of bailing wire was cast in the walls and bottom to represent the reinforcing steel, while a coil of wire supported inside the "pot" and in contact with the cage represented the hot water coils. The sludge stirring mechanism was represented by a grid of wire supported in the middle. Several wires were brought out for electrical connections and the "pot" was filled with sludge liquor.

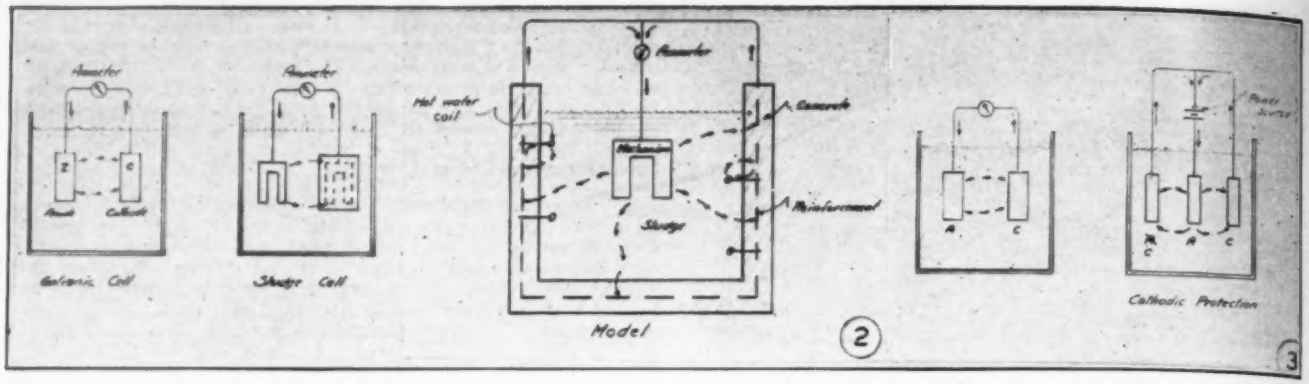
Diagram No. 2 shows the arrangement of "pot" model. The parts indicated as "reinforcement," "hot water coil" and "mechanism" were baling wire.

Readings made with the sensitive voltmeter showed that current flowed through the instrument from the wire cage which was encased in concrete to the grid which was suspended in the liquor. This proved that the "pot" was acting as a battery and that a self-generated current passed from the wire grid (anode) through the liquor electrolyte to the wire cage in concrete, which was the cathode. The current passed back through an external wire to the anode, thus completing the circuit. Current also probably flowed from the wire which represented the hot water coil to the wire cage, and back to the coil through the supporting wire, although this could not be proven.

However, after exposure for about three weeks, with the cage externally connected to the grid, a noticeable amount of corrosion was found to have occurred in wire representing the hot water coil, as well as in the grid representing the sludge and scum mechanism.

It was suggested that a possible source of electric current might be the maze of piping which connects the various parts of the plant. These pipes of various materials, are for the most part, buried in the damp, salty sand of the plant site and may at times be in brackish ground water.

This theory was based on the well known fact that pipes passing through varying types of soils are subject to electrolytic corrosion. In this case, the pipes buried in the ground would be cathodic while the other ends, being in contact with the sludge in the digester, would be anodic and, therefore, would be corroded. However, the experiments with the "pot" model, already mentioned, proved that current was produced when the model



Diagrams 1-2-3—Revealing Similarity Between a Simple Galvanic Cell and That Produced With Electrodes in Sludge Liquor, as the Electrolyte

(1) Galvanic Cell and Sludge Cells. (2) Concrete Model of Sludge Digester Used in Study of Current Flow Resulting From Galvanic Action. (3) The Simple Galvanic Cell After the Introduction of a Sacrificial Anode Between the Two Electrodes and Reversal of Current Flow. Thereby, What Was Originally the Anode Becomes Another Cathode, Thus Producing So-called "Cathodic Protection" When the Imposed Current Reverses the Flow of Ions.

was standing on a bench and *not* in contact with the ground—i. e., was in nowise grounded.

A test was made to simulate conditions to test the above theory. The "pot," partly buried in the sand, was connected to a quantity of junk iron buried nearby. This sand was well-soaked with ground water and conditions of current flow noted. It was found that a small current, probably not over 15 per cent of the total, was produced by the buried iron and the remainder (85 per cent or better) was produced inside the "pot." It was concluded that, due to the smaller relative area and to faulty electrical contact, the piping system of the plant would deliver but a negligible amount of current to the digester.

The Digester Studied

After a very careful consideration of all the foregoing evidence, it was concluded that the corrosion which had occurred in the digester had been caused by an electrolysis due to a self-generated or galvanic current within the digester itself.

Further investigation was made to find the cause of the "spotty" condition of the corrosion in the digester, particularly as to why some of the manhole steps and pipe hangers were severely attacked and some were not. It was found by passing a small electric current from a flashlight battery through the various parts, that the steps and hooks which were corroded were apparently in good contact with the reinforcing steel in the concrete walls of the tank, while those which were not corroded were in poor contact or not in contact at all. This poor contact would prevent the completion of an electrical circuit without which electrolytic (galvanic) corrosion could not occur.

It could only be assumed that the "spotty" conditions of structural steel members and some portions of the piping was caused by the fact that some of the original bituminous paint coating adhered to some areas and caused a concentration of current on the unprotected areas.

Considering the digester as a whole, the electrolytic conditions which could have caused the corrosion were now considered as being somewhat as follows:

The hot water pipes, being directly exposed to the sludge and therefore, by reason of their environment, dissimilar from the steel of the reinforcement, acted as anodes. Current flowed through the sludge electrolyte to the cathodic reinforcing steel embedded in the damp concrete and thence back to the pipes through the supporting hooks which were in contact with the steel. The pipes, being anodic, were eaten away. (By referring to Diagram No. 2 and imagining that the external lines leading to the ammeter represent the massive steel and concrete roof structure, the reader will have less difficulty in following the writer's explanation.)

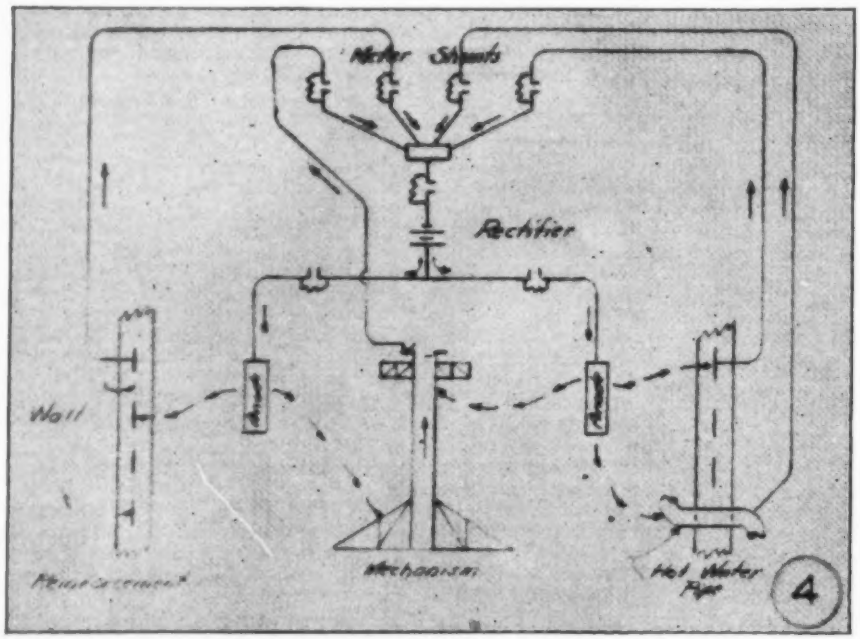


Diagram 4—Cathodic Protection Diagram as Applied to Sludge Digesters Sketch Reveals Arrangement of Sacrificial Anodes and Reversed Current Flow Onto Metal Parts of Digester to Be Protected, and Its Return Through Metering Shunts. The Imposed Current Follows the Path of Least Resistance, Which Is to Exposed Metal Where Corrosion Is Most Active and Protection Most Needed.

In the case of the sludge stirring mechanism, the structural steel members were also anodic and current passed through the sludge to the reinforcing steel. This steel, being in contact with the roof of the tank, itself of reinforced concrete with steel beams, passed the current to the rotating sludge mechanism through the driving machinery and thrust bearings, thus completing the circuit. Here again, the steel members of the stirring mechanism, being anodic, were corroded.

While the data obtained in the investigations did not definitely prove that the corrosion had been caused in the manner above stated, it seemed that all of the facts fitted the theory and that no other theory fitted all of the facts. It was therefore decided to proceed to devise protective measures on this basis.

Protective Measures Adopted

At first, an effort to insulate the various parts was considered. This would have been extremely difficult, if not impossible, and at best would have been unreliable, due to the many possible paths for the flow of current. It could not have been accomplished without extensive reconstruction of the tank.

Protective Coating

It was decided to sand blast all of the exposed metal in the tank and to cover the parts with a good bituminous coating. After sand blasting, the parts were given a prime coat of Wailes-Dove-Hermiston Corporation's "Bitumastic" solution, followed by two

coats of hot "Bitumastic" enamel, mopped on. This material produces a thick, rather rough and brittle coating but when properly applied gives good protection. (See Figures I and II.) A coating, however, on such surfaces, cannot be applied so as to give 100 per cent coverage and it was realized that additional protection by other means would be required. In fact it was quite likely that a 99.9 per cent covering would be worse than no covering at all. For if the cause of the corrosion was to continue unabated, all the attack would be concentrated on the uncovered areas. This would result in the prompt and complete failure of the unprotected parts.

Cathodic Protection Adopted

After considerable study and inquiry, it was decided to test the method of anti-galvanic action known as "cathodic protection" which has for some time been used to protect oil, gas and water pipe lines from external soil corrosion; and more recently applied to water towers and tanks for stopping internal corrosion.

This method of protection has as its basis the fact that if a metallic surface, which would otherwise be anodic and therefore subject to electrolytic corrosion, be made cathodic by externally applied direct current, that surface cannot be corroded and is therefore protected.

Diagram No. 3 illustrates the principle of cathodic protection. At the left is a simple galvanic cell, identical to Diagram No. 1. As shown, the anode would be eaten away while the cathode is unaffected. However, if another plate is inserted into the cell (Diagram 3—right) and connected to a power source externally as shown, then the new plate becomes the anode and both of the original plates become cathodes. The former anode is now cathodic and is no longer corroded.

In this system, two things are apparent. The potential (voltage) of the new power source must be greater than the natural potential of the cell itself, which is usually small. Also the new anode would eventually be destroyed—sacrificed to save the other surfaces. Such anodes are known as "sacrificial" anodes.

In the case of pipe lines, the pipe to be protected is connected by wire to the negative side of some direct current power source, such as a motor generator set or a rectifier unit, the positive side of which is connected to a so-called "sacrificial" anode, usually some sort of junk iron. The anode is buried in the ground at some distance from the pipe. Current coming from the power source passes first by wire to the anode, then through the ground to the pipe, returning by wire to the source. The pipe thus becomes negative to the anode and the latter is destroyed instead of the pipe. Hence the name "sacrificial." The cost of replacing the junk iron anodes is small, as is also the cost of power required.

In protecting the interior walls of steel tanks the tank is made cathodic and dc. current flows from the anode suspended in the tank, through the water and to the tank walls.

It must be understood that, while theoretically such a method should provide complete protection, due to the numerous uncontrollable factors encountered in the field the conditions causing corrosion can only be mitigated to a large extent. In any case, the life of the pipe line or tank is greatly extended and the cost of protection is well worth while.

Application and Arrangements

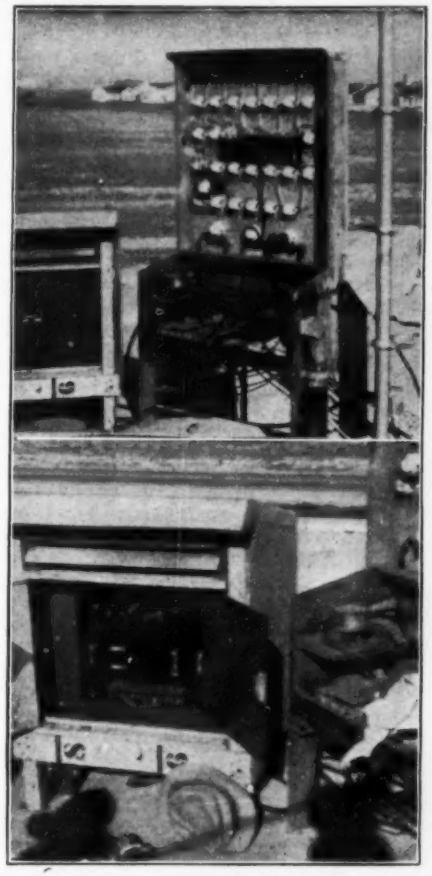
While there was no precedent to be followed in the case of a sewage digester, it was felt that the cathodic-protection scheme could be used to advantage, and would reduce, if not entirely prevent, the necessity of costly replacements in the near future.

Two anodes were provided, one being hung through each of the two manholes in the roof of the digester. These anodes were steel plates eight feet long, two feet wide, and one-quarter inch thick, suspended by two one-inch diameter iron rods welded to the plates and supported from wooden frames in the manholes. The iron supporting rods were later found to be badly attacked and were replaced by two-inch by four-inch redwood hangers. The hangers were long enough so that the plates hung vertically in the upper zone of sludge, with the tops about two feet below the surface. Heavy copper cables protected with heavy rubber covers were connected to the plates and carried out of the manhole and across the roof to the central platform of the digester.

A Westinghouse "Rectox" rectifier (see Fig. V), connected to the lighting circuit, provided direct current. The two anode cables were connected to the output or positive terminals of the rectifier. The return or negative terminals were connected to the main bus of a test panel.

In order to provide for definite return paths for current from the various parts of the tank, individual wires were connected to these parts and brought to the test panel. Connections were made to the hot water pipes at three points outside the tank, to all sludge and other piping, to the steel beams supporting the roof, to eight points in the steel reinforcement, to the driving machinery and by sliding brush contacts to the upper part of the stirring mechanism. In all, thirty-two such connections were made, each with its individual wire to the test panel.

The test panel (see Figure IV) consisted of a sheet of "masonite," about five feet high and thirty inches wide, in the center of which a brass bus plate was fastened. Mounted on the panel were thirty-five polarized porcelain receptacles, one for each return wire, one for each anode cable and one for the main return to the rectifier. Each return receptacle was fitted with a home-made shunt, of three ampere capacity, across the terminals and on one side was connected to the main bus plate. Each return wire was connected to its respective receptacle and correctly labeled. Twenty-five ampere shunts were fitted across each anode cable receptacle, and a fifty ampere shunt was fitted across the main return receptacle.



Figures IV and V—Cathodic Protection Equipment

(Above) Test Panel, With Metering Receptacles, Shunt sand Ammeters. On Left Is the Rectifier Which Converts Alternating to Direct Current. (Below) The Compact Westinghouse "Rectox" Copper-Oxide Type Rectifier in Temporary Housing.

Two ammeters were provided, each with cords and polarized plugs attached, one ammeter reading to three amperes positive or negative, the other reading to one hundred amperes, positive.

Diagram No. 4 shows the schematic arrangement of the various parts of the protective system. For simplicity, only four of the return connections are shown. The supply circuit to the rectifier is not shown. The supply is 120 volt, 60 cycle, A.C. current, only about 60 watts of energy being used all told.

When the apparatus is in operation the circuit is as follows: Current leaving the rectifier passes through the anode shunts to the anode plates. Thence it passes into the sludge, and through it to the hot water coils, stirring mechanism, reinforcing steel and other metal parts. From these parts it goes by the individual return wires to the receptacles on the test panel, and through the

shunts to the bus plate. From the bus plate it passes through the main return shunt to the rectifier.

The purpose of the shunts is to provide for measuring of the current without interrupting the circuit. The anode shunts permit the current passing to each anode to be measured separately. The individual shunts permit measurement of the current returning from each part of the tank to be protected. The main return shunt provides for measurement of the total current returned and serves as a check on the other readings. The readings on the individual returns permit these circuits to be balanced in approximate proportion to the area to be protected, and also indicate whether the connections are in good condition.

The Westinghouse rectifier has a capacity of 30 amperes at 3.2 volts, direct current, and is so designed that several combinations of voltage and amperage may be obtained. However, experience dictates that those tappings which produce 20 amperes at 2.2 volts should be used; and, thereby, the total power used is only that required for a medium size electric light. One-half the current is sent to each anode and the return circuits are balanced to carry from 0.25 to 1.5 amperes each. Readings are made and recorded periodically to note changes.

The Anodes

The steel-plate anodes are hoisted out for inspection from time to time and are replaced as needed—(see Figure VI). When removed, the plates are found to be covered with a black honeycombed crust about two inches thick, while underneath the crust the plates are deeply pitted and eaten away at the edges. The wooden hangers are not affected, nor does the crust seem to affect the operation of the plate as an anode. One pair of plates, originally weighing 195 pounds each, were found to weigh 90 pounds each, after fourteen months of service. Each plate lost, therefore, 105 pounds or 7.5 pounds per month. This equals approximately 9 pounds of iron per ampere per year. Figure VII shows the condition of an anode, after final removal. This plate has been left in service too long. It is probable that the anodes should be replaced after nine to twelve months' service at the Terminal Island plant. At other plants the service period per anode may be longer or shorter, depending upon local conditions.

The cost of the installation was about $200.00, of which $140.00 was for the "Rectox" rectifier. This cost does not include labor, which was done by the plant operators, under the supervision of the writer. It is indicated that anode replacements will cost $10.00 to $15.00 per year, depending on conditions. The power cost is truly negligible.

Most of the anti-galvanic cathodic protection equipment was put in operation about the middle of December, 1938, using a home-made motor-generator set for power supply. The "Rectox" unit was purchased and installed later.

Results

It is unfortunate that no definite information can be given at this time as to the results of this method of protection, as no opportunity has occurred to make a complete inspection of the interior of the digester. Three things, however, seem to indicate that the protection has been effective.

First: On May 5, 1939, after about five months of operation, an inspection was made of the scum and upper mechanism in the digester, and the previously attacked parts of the scum breaker truss were found to be in excellent condition, the "Bitumastic" coating being intact. This indicated that no noticeable corrosion was taking place in this part of the merchanism.

Second: If the corrosion had continued at the alarming rate that it had during the first fourteen months, it seems highly probable that some of the structural parts of the mechanism would have failed entirely in the nearly two years of operation since the protection was installed.

It was gratifying to note that, when for test purposes, the rectifier was shut off, the current in certain of the individual return circuits immediately reversed. This was exactly what was to have been expected from the results of the experiments with the "pot" model, indicating that the conclusions drawn therefrom had been correct. It also indicated what might have been expected if anti-galvanic protection had not been applied. Further than that, it indicated that all spots could not be reached with the protective coating applied to the metal parts in place.

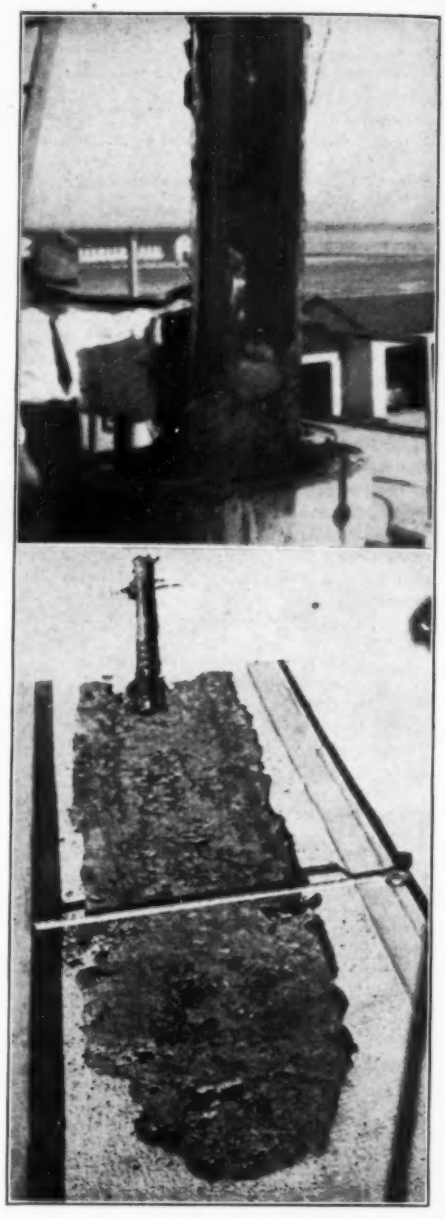
In the near future it is planned to install new sludge mixing equipment and new vertical type heating coils in the digester, to convert it into the first stage of a two-stage system, which will involve use of the decantation tanks as secondaries. When the tank is emptied for this work, a complete inspection will be made. It is our intention to make the results of this inspection and subsequent opinions, or changes in procedure, public at a later date.

In the meantime, the writer hopes that others will interest themselves in the matter of possible electrolytic corrosion, not only in digesters, but in other units of treatment plants as well.

Acknowledgments

The writer is indebted to Mr. Otto Wiemer, earlier mentioned in this paper, for his assistance in the field and laboratory and the solution of the problem was in a large measure due to his wide knowledge of the fundamentals of electrolysis and electricity in general. The plant operators, particularly Mr. Fiscus, Chief Operator, deserve praise for their help and ingenuity in solving many problems of application.

The Terminal Island Sewage Treatment Plant is part of the sewer system of the city of Los Angeles, California, and is operated under the Board of Public Works. Mr. Lloyd Aldrich is City Engineer. Mr. H. G. Smith is Engineer of Sewer Design and the writer was, at the time of these investigations, Assistant Engineer in charge of plant operations.



Figures VI and VII—The Inexpensive Sacrificial Steel Anode

(Above) Hoisted Out for Inspection. Note Crust Adhering to Plate. (Below) An Anode After 14 Months of Service; Little Being Left But Metal Lace and Wood Frame. Frame Strips Show Original Size of Anode.

THE VAPOR RECOVERY SYSTEMS CO.

COMPTON — NEW YORK, N. Y. — *The Pace Setter since 1928* — TULSA, OKLA. — CALIFORNIA — HOUSTON, TEX.

Agencies Everywhere

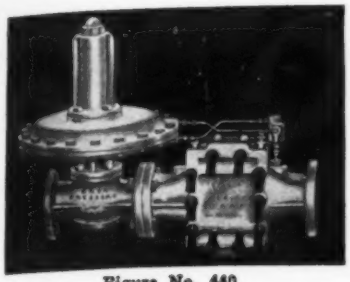


Figure No. 440

Sizes	2"	2½"	3"	4"	6"
Sh. wt...	125	140	160	200	260

←THE NEW "VAREC" *Approved* PRESSURE RELIEF AND FLAME TRAP ASSEMBLY

Unit consists of Diaphragm-operated Regulator, Flame Trap, and Thermal Shutoff Valve. Maintains a predetermined back pressure, passing surplus gas to Burner. Stops flame propagation. Patented telescopic flame trap element simplifies inspection and maintenance. Listed by the Underwriters' Laboratories for vent lines in oil tanks.

Figure No. 58C

"VAREC" *Approved* PRESSURE RELIEF AND VACUUM BREAKER VALVE WITH ←—FLAME ARRESTER

Installed on digesters and gas holder domes, it affords emergency Pressure and Vacuum Relief and prevents flame entrance from atmospheric disturbances. Equipped with telescopic Flame Arresting element for easy inspection and maintenance. Pure aluminum. Non-corrosive. Listed by the Underwriters' Laboratories for Vent Lines in oil tanks. Sizes 2" to 10".

Sizes	2"	3"	4"	6"
Sh. wt.	70	105	160	225

"VAREC" *Apporved* WASTE GAS BURNERS——→

Installed wherever disposal of surplus gas is a problem. Unit has adjustable air intake in the venturi tube, pilot valve adjustable from outside. Long, heavy cast iron draft stack insures proper draft and complete combustion.

Sizes	2"	3"	4"
Sh. wt.	450	480	500

Figure No. 236

Figure No. 450

"VAREC" *Approved* FLAME TRAP ASSEMBLY

Flame Trap and Thermal Shutoff Valve. Unit self-contained, simple, foolproof. Installed in all gas lines supplying gas utilization equipment. No expensive fitting-up necessary. Arrests flame propagation. Easy inspection and maintenance. Aluminum and stainless steel. Non-corrosive. Flame Trap Element listed by Underwriters' Laboratories for vent lines in oil tanks.

Sizes	2"	2½"	3"	4"	6"
Sh. wt....	90	100	115	150	200

Figure No. 220A

"VAREC" *Approved* MANHOLE COVERS

Installed on digester and gas holder domes, affords quick and easy access. Has square, graphite-impregnated, fire proof gasket. Nonsparking. Gas-tight.

Sizes	18"	20"
Sh. wt.	100	110

Figure No. 51A

"VAREC" *Approved* FLAME CHECK

Acid resisting. Union type fitting. Positive flame stop for small lines. Has five 40-mesh fire screens. Easy inspection and maintenance.

Sizes	½"	¾"	1"
Sh. wt.....	10	10	10

Figure No. 216A

"VAREC" *Approved* MANOMETERS

Single or Triple tube. Open or push-button control types. Accurate. Aluminum housing. Bronze fittings. Pyrex glass. Automatic—Fireproof—Safe. Sizes 6" to 36".

Sizes	9"	12"	15"
Sh. wt.....16	18	20	

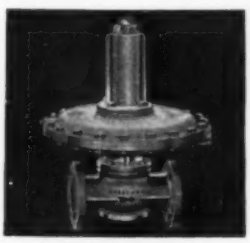


Figure No. 387

"VAREC" *Approved* SENSITIVE PRESSURE (REDUCING) REGULATOR SINGLE PORT

Maintains upstream or downstream pressure to within 0.5" of water of predetermined pressure. Positive Shutoff. Aluminum body. Throttling type inner valve. 18-8 stainless steel trim. Sizes 2" to 6".

Sizes .	2"	2½"	3"	4"
Sh. wt.	100	115	140	175

Figure No. 211A

"VAREC" *Approved* BACK PRESSURE (REDUCING) CHECK VALVE

Installed in relatively low pressure gas lines. Prevents back-flow through meters. Non-chattering, non-pulsating, non-corrosive, non-sparking.

2"	3"	4"	6"
20	35	70	125

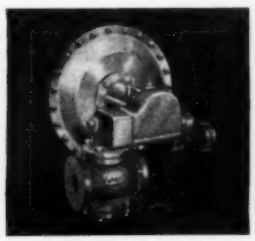


Figure No. 187

"VAREC" *Approved* SUPER SENSITIVE PRESSURE (REDUCING) REGULATOR DOUBLE PORT

Maintains upstream or downstream pressure to within 0.2" of water of predetermined pressure. Standard working parts 18-8 stainless steel with synthetic rubber diaphragm. Non-corrosive. Sizes ½" to 10".

2"	2½"	3"	4"	6"
190	200	233	260	350

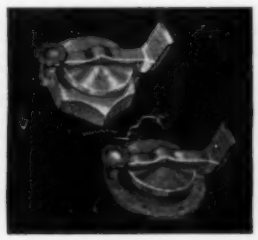


Figure Nos. 48 and 42A

"VAREC" *Approved* SAMPLING HATCH COVERS

For use on digester domes. Available in several combinations of materials. Non-corrosive, gas-tight, self-closing, spark-proof. Figure 42A Flanged and Figure 48 Screwed.

4"	6"	8"	10"
12	17	23	27

Figure No. 232D

"VAREC" *Approved* SEDIMENT TRAP AND CONDENSATE DRIP TRAP ASSEMBLY

Cast iron construction. 18-8 stainless steel working parts. Hand operated or automatic. Sizes 2" 2½"-3"-4".

SEND FOR THE NEW "VAREC" SEWAGE CATALOGS-3 NOW

GAS HAZARDS*

Methods of Reducing Such at Sewage Treatment Plants

PART I
OPERATION AND MAINTENANCE

Instructions to Operators and Superintendents

Sewers.

a. Solids should never be allowed to accumulate in sewers to give off gas during their decomposition. Frequent inspection, by means of gas detectors, are suggested to determine if explosive or toxic gases are present. Periodic flushing of sewers is also suggested, particularly in sections at flat grade or near dead ends.

b. Inflammable or volatile liquids, such as petroleum products, oil or cleaning solutions, should not be permitted to gain access to the sewers. Garages, dry cleaning establishments, or any building handling volatile or inflammable liquids should be equipped with traps on their sewer connections to intercept such liquids at their source. Frequent inspections of establishments using such products are required to eliminate this all too frequent source of danger. Persuasive letters or the enforcement of a local ordinance or fire code may be used to enforce their exclusion.

c. As much ventilation as possible should be provided. Any complaint relative to odors from sewers must be given careful consideration, the odor traced to its source and eliminated rather than sealing manholes and thus permitting what could easily be an explosive or toxic gas to increase in concentration.

Plant Odors or Sanitation.

a. All pockets which collect solids should be eliminated and ventilation ducts should be maintained at all points where gas might accumulate. The vapors caused by gasoline and similar products are heavy and should be removed from low points of enclosures, preferably at the point of entrance to the plant, while the so-called sewer gas is lighter than air and must be removed at the top of enclosures (incoming sewers must be trapped to provide positive ventilation). Where provided ventilating systems should be used at all times. Where no ducts or fans are provided their installation should be urged. A mixture of air and inflammable gases in ducts is liable to be explosive, therefore, the blower must be of the non-sparking type suitable for such work and the motor must be as approved by the National Board of Fire Underwriters for hazardous atmospheres.

b. Screen chambers, weir chambers, channels and all pockets where sludge or floating solids may accumulate should be flushed clean at least one daily; more often in summer. Any sludge or supernatant liquor spilled during sampling or drawing should not be allowed to stand to give off dangerous gases or odors. Water or clarified effluent under considerable pressure should be available for these purposes.

c. Scum and screenings should be removed daily.

d. Wet wells at treatment plants or outlying pumping stations should be maintained clean enough, at all times to prevent gas formation.

(The above applies to the removal of sources of gas formation which will, by their toxic effect, lower the vitality of the plant personnel if not present in sufficient concentration to become lethal or explosive. The gases present at sewage treatment plants do not always give warning of their presence by the sense of smell.)

Plant Operation.

a. Care must be exercised in drawing sludge or supernatant liquor from digestion tanks with fixed covers. At no time should the liquid level in this type of digester be lowered to a point where the gas is no longer under pressure. The installation and use of gas storage devices cannot be too strongly recommended to compensate for the lowering of liquid level in digesters. Where gas storage units are provided, no attempt should be made to lower digestion tank levels unless sufficient gas is stored to compensate for such lowering of liquid levels; an alarm on gas holders could be installed to warn when the volume of gas is lowered to a predetermined level. Gas holders or floating covers should never be permitted to come to rest (grounded) unless they are to be taken out of service, in which event they should be purged with an inert gas under competent supervision. (Information relative to purging may usually be obtained from local gas engineers.)

b. Sludge levels should be held low enough below gas domes or outlet pipes to prevent the entrance of solids to gas lines. A float operated pump cut-off switch, alarm, or overflows are recommended to keep the scum level(s) below a predetermined point.

c. A daily examination should be made of the liquid levels of all seals. Any liquid displaced or lost by evaporation should be immediately replaced. The use of a non-evaporating anti-freeze solution is recommended.

d. It is suggested that a chart be set up requiring the daily or hourly notation by the operator or assistants of any data pertaining to gas pressures, sludge levels, liquid or sludge to and from the digestors, gas production, attention to seals or any other data relative to the safe handling of sludge gas. A monthly check of conditions of safety and first aid equipment is recommended.

Safety Measures.

a. All gas handling equipment should be maintained gas tight. Joints should be periodically tested by a soap test for leaks.

b. "U" traps, drips or any outlets into enclosed space should not be permitted. Any such outlets found should be eliminated or, if necessary, vented out-of-doors. Under no condition should they be vented to sewers.

c. All enclosed spaces should be properly ventilated (forced ventilation preferred) so that, should leaks in gas handling equipment develop, no toxic or explosive mixture will be built up. Confined spaces frequently used should be constantly ventilated and less frequented enclosures thoroughly ventilated before use.

d. As a precautionary measure, but far from foolproof where explosion hazards exist, all possible sources of ignition should be eliminated—such as:

Flames: Open lights. matches, cigar lighters, fires, blow torches.
Sparks: From tools, lightning, static, electric shorts, motors.
Heated Materials: Heated metals, hot cinders, glowing tobacco.

The judicious use of "No Smoking" signs is recommended where explosion hazards exist. Too liberal use of these warnings tends to minimize their effectiveness. The use of electrical equipment designed for hazardous atmospheres and spark-proof tools is recommended.

e. Electric motors should be permanently and effectively grounded.

f. It is strongly recommended that whenever it becomes necessary to enter any enclosure—such as a digestion tank—in which an oxygen deficiency or an explosive gas or toxic gas is liable to be found, the following precautions be observed: Completely drain any residue of sludge and purge the tank with water and/or an inert gas. Do this with a minimum of manhole disturbance to prevent possible ignition by sparks. Thoroughly ventilate (force draft if possible, never suction unless by means of spark-proof blowers and motors). A workman (or workmen) must never attempt, or be assigned, to enter such an enclosure unless they are equipped with a gas mask of the hose or oxygen helmet type (never canister) and a safety harness (not simply a rope tied around his body) to which is attached a rope strong enough to support his weight, tied at the top and attended by sufficient man power to pull him out if necessary. Maintain communication between the men in the enclosure and those on top. Rubbers or boots should be worn and a great deal of caution observed to prevent sparks from tools or static electricity such as rubbing or striking metal buttons. Masks and safety harnesses must be kept dry and their condition checked frequently. Never attempt to use this equipment without thoroughly testing. All plant personnel should be thoroughly familiar with their use. Only lights that are approved by the National Board of Fire Underwriters for hazardous atmospheres must be used. These same precautions should be observed with the necessary modifications when entering or working in sewer lines. Air and digestion gas must never be mixed in digesters, piping or any gas handling equipment. When digestors or equipment are placed in service or taken out of service, the entire system must be purged with water, an inert gas, or a combination of the two.

g. Gas and oil burners should be installed and used under local

*From the 1940 report of the Committee on Hazards of the N. J. Sewage Works Association.

ordinances or codes and the National Board of Fire Underwriters codes relating to such equipment.

h. A supply of chlorine should be maintained in any process building sufficient for normal demands only. The main supply should be stored in a detached non-combustible building or, if in a room attached to the main building, it shall be of fire-proof construction and separated from the main part of the building by a fire-proof door constructed under the regulations of the National Board of Fire Underwriters. The room or building should be used for no other purpose and should be kept locked at all times to prevent the entrance of unauthorized persons.

i. Two yellow canister masks should be provided for use in chlorinous atmospheres. They should be kept in a dry place which is handy to chlorine storage or use, yet not liable to exposure to chlorine fumes in event of leaks. Every man at the plant should be thoroughly familiar with their use.

Safety Equipment.

The following equipment is recommended for all sewage treatment plants at which sludge gas is collected or burned:

a. A hose mask or oxygen helmet, a safety harness [and two yellow canister masks for use in chlorine gas if included in treatment.)

b. Fire Extinguisher. One 2½-gal. foam or one 15-lb. CO_2 extinguisher should be provided for each 2500 sq. ft. of floor area, or for not over 50 ft. of travel to reach the nearest extinguisher.

c. Sewage treatment plants should be provided with a suitable instrument for detecting explosive gases and for detecting H_2S. Illuminating gas in sewers may be detected by means of relatively cheap ampoules which indicate the presence of carbon monoxide (CO). A Wolf safety lamp, explosion meter, Orsat apparatuses, or similar equipment are required to test for explosive mixtures. Hydrogen sulphide (H_2S) may be detected by several commercial apparatuses or by a 5% solution of lead acetate.

d. First aid equipment. Personnel employed at sewage treatment plants should have a knowledge of artificial respiration, knowledge of the location of the nearest safety team equipped with an inhalator, and list of doctors and other aids to be called in emergency. (The local gas or electric company usually maintains a safety squad equipped with an inhalator.)

It is suggested that operators and their *assistants* attend first aid meetings and familiarize themselves with first aid and artificial respiration methods. It is suggested that night operators or single operators be required to call the local police station or some other agency hourly and that failure to do this will result in a check-up of the operator's condition by the police. An accident may thus be prevented or a life saved.

e. Manometers or other pressure indicating devices, located at points visible from valves or other controls used to change the levels of digestion tanks, which will indicate gas pressures within the digester and at all other seals. Manometers should be installed in such a manner that the liquid contained therein cannot be blown out to permit the escape of gas into any enclosure.

f. A telephone for use in summoning aid in case of fire, explosion or asphyxiation.

PART II

PLANT DESIGN, PIPING, EQUIPMENT

Sludge Digestion Tanks.

1. *Tanks:*

a. Covered separate sludge digestion tanks shall be provided with means to maintain gas under pressure at all times to allow for reasonable operating fluctuations of liquid or scum levels. Fluctuations in liquid or scum levels will be considered in relation to the volume and moisture content of raw sludge. For domestic sewage, this volume should be from a minimum .3 cubic ft. per capita for plain sedimentation to a minimum of .5 cu. ft. per capita for activated sludge.

b. Covered separate sludge digestion tanks shall be constructed or treated so that they are impervious to gas, and no buildings shall be erected over them.

c. All openings in tanks with fixed covers shall be sealed gas tight. Curtain walls or sampling pipes shall extend at least 6 in. below reasonable operating levels as required in section 1 (a).

d. All closed digestion tanks shall be provided with means for safe disposal of gas as further provided in these recommendations.

2. a. Where gas is collected, domes or similar devices shall be provided at the high point(s) of the digester cover.

b. A safety pressure release with adequate flame protection shall be provided for each collecting dome or floating cover. This device shall be installed to release excess pressure directly from the digester. It shall be designed to operate at a pressure of at least 2 in. of water above maximum operating pressure.

Pipe Lines.

1. *Piping:*

a. Pipe lines to be used for the collection and transmission of digster gas shall be of gas tight construction and shall be pitched with a grade of not less than ½ in. in 15 ft. with drips provided at low points. Consideration should be given to the insulation of exposed lines to prevent freezing of moisture. All piping shall meet the Good Practice Requirements of the National Board of Fire Underwriters.

b. No siphon or "U" taps shall be installed on drips and all automatic drip discharges shall be to a point outside any enclosure. In no case shall this be to any sewer or pipe line.

c. Minimum pipe sizes for gas lines shall be 2½ in. Non-insulated lines exposed to freezing temperature should be double the above capacity. It is suggested that all gas piping be three times its designed capacity.

d. Pipe lines to gas engines shall be suitably protected against flame propagation and excess pressure. All such lines should be independent of all other piping. Sizes and appurtenances shall be determined by the specific engine requirements.

e. Valved by-passes should be provided for all meters.

f. Means should be provided to permit purging all gas handling equipment of sludge gas or air.

g. Means shall be provided to prevent the accumulation of sludge or supernatant liquor in sampling sinks or channels within enclosures.

2. *Valves:*

a. Shut-off valves should be provided for the sub-collection lines for each tank and in the main line before and after the pressure relief and flame traps.

b. Pipe lines or valves shall not be installed permitting the by-passing of flame traps or pressure reliefs.

Equipment.

1. *Pressure Regulation:*

a. Means shall be provided to maintain a minimum working pressure of 2 in. of water in gas piping at the point[s) of consumption.

b. Equipment or devices shall be provided which will confine the fluctuations in working pressure within the gas piping system to a definite limit or range (see also Waste Gas Disposal).

c. Any equipment or device designed for the collection or storage of gas in which excessive pressure may be built up when the flow of gas therefrom is stopped shall be equipped with a device that will permit the escape of gas. It shall discharge at a minimum of 2 in. water pressure over the pressure required in the unit to maintain the designed maximum working pressure within the gas system. Such gas discharges shall not be to any enclosure.

2. *Flame Trap(s) or Arrestors(s):*

a. A flame trap shall be provided close to the service end of all supply pipes, with no connection to a gas consuming unit between the flame trap and source of supply not protected by another flame trap.

b. Flame trap(s) shall be suitably protected from the elements.

c. Where gas engines are to be used, separate flame traps shall be installed on the line (see "Pipe Lines" 1 [d).

3. *pressure Relief(s):*

a. An automatic pressure relief shall be provided suitably protected from the elements.

b. Where gas engines are to be usd, a separate pressure relief shall be installed, of the dry seal type (see "Pipe lines" 1 (d).

4. *Seals and Vents:*

a. Equipment requiring liquid seals shall be provided with indicators clearly showing the liquid levels to be maintained and means shall be provided to introduce an additional supply of sealing liquid.

b. Liquid seals on equipment in locations exposed to freezing temperatures shall be anti-freeze solution.

c. Vents or drip discharges shall be piped to the outside and not to any sewer or pipe line.

5. *Waste Gas Disposal:*

a. A waste gas line shall be provided which will discharge into the atmosphere at a point outside the building at a height sufficiently above ground or surrounding structures to insure proper and adequate dilution, or to a protected burner.

b. The excess gas line shall be free of valves or other possible obstructions.

6. *Waste Gas Burners:*

a. Waste gas burners shall be designed and installed so as to maintain a flame in high winds or rain and shall be provided with a flame trap and a pilot from the outlet side of the main flame trap or an individual flame trap.

b. Waste gas burners shall not be placed nearer than forty (40) ft. from digestion tanks or twenty [20) ft. from any building. They may, however, be placed at least five (5) ft. above flat roofs or two (2) ft. above ridges of gable roofs of buildings provided they are at least fifteen (15) ft. from any higher story or any adjacent building and the roof is of fire-proof construction.

7. *Gas Meters:*

The installation of gas meters is recommended to measure the production and consumption of gas.

8. *Pressure Gages:*

a. A gage, or gages, to show in inches of water (or equivalent) the gas pressure in the digestion tank shall be provided and located so as to be visible at the points of control for the withdrawal of sludge and supernatant liquor.

b. Pressure gages in the line(s) before and after the flame traps and at points of gas utilization are desirable.

c. Manometers shall be designed to prevent escape of gas into any enclosure caused by a blow out of liquid.

9. *Boilers:*

a. Gas and oil burners should be installed and used under local ordinances or codes and the National Boar of Fire Underwriters codes relating to such equipment.

b. Flues from gas heaters shall be separate from building heating plant shimney and shall be carried above roof a minimum distance of three [3) ft. above flat roofs or two (2) ft. above ridge of gable roofs, or if near chimneys an additional height of at least eighteen (18) in. above adjacent chimneys.

c. Siphonage or other type of ventilators on top of flues that will prevent backdraft are recommended.

10. *Gas Holders:*

a. Where gas holders are installed to compensate for differences in liquid or scum elvations in digestion tanks, they should have capacities as required under "Sludge Digestion Tanks 1 (a)." They shall be connected so that any lowering of liquid level in the digester is compensated for by a flow of gas from the holder to the digester. Alarms or cut-off switches are recommended to maintain the volume of gas in the holder above a predetermined minimum.

b. The capacities of gas holders to be used in conection with gas engines shall be considered in relation to the engine requirements.

c. Gas holders of the high pressure type shall include a balancing suction tank and automatic regulators to pump controls.

11. *Ventilation:*

a. Forced draft ventilation shall be provided with outlets at or near the sewage level in enclosed screen chambers, covered sedimentation tanks, and at all points where either heavy or light gas may accumulate. Ventilation by suction is recommended.

b. Ventilating fans shall be of the non-sparking type suitable for hazardous atmospheres. Motors shall be so mounted that no contact is made with the air in ducts or blowers and shall be constructed as approved by the National Board of Fire Underwriters for hazardous atmospheres. Electric motors shall be permanently and effectively grounded.

12. *Housing of Equipment:*

a. Where installed in buildings, heating equipment, flame traps, pressure reliefs, gas meters, etc., shall be located in a separate building or room. The room shall be cut off from the rest of the building by fire-proof walls as approved by the National Board of Fire Underwriters. The entrance to the room or building shall be from the outside and through a door designed to swing outward.

b. The floor of the building or room housing such equipment shall not be located below the ground surface and, if over or under other parts of a building, shall be of gas-proof construction.

c. The room or building shall be ventilated at both the floor and ceiling.

d. The walls of the building or room shall have liberal glass area consisting of thin glass sash. Where, because of exposure, it is necessary to use wired glass, sash shall be so hung that they will readily swing out in case of an explosion. Such sash shall not be secured.

e. All electric wiring, including lights and switches, shall be as approved by the National Board of Fire Underwriters.

f. The use of individual gas heaters is not recommended to burn sludge digestion tank gas.

13. *Safety Equipment:*

a. A hose mask or oxygen helmet and safety harness shall be provided.

b. One 2½-gal. foam or one 15-lb. CO_2 extinguisher should be provided for each 2500 sq. ft. of floor area, or for not over 50 ft. of travel to reach the nearest extinguisher.

c. Gas detectors for inflammable or toxic gases are recommended.

d. A telephone is recommended.

14. *Chlorine:*

a. A separate building or room of fire-proof construction as approved by the regulations of the National Board of Fire Underwriters shall be provided for chlorine storage. It shall be designed solely for chlorine storage, adequately ventilated and its door provided with a lock.

b. Gas masks for use in chlorinous atmospheres are recommended.

Edward F. Shissler, *Chairman*, Leigh Morril, *Secretary*
R. M. Cadman, I. R. Riker.

Limits of Flammability of Gas-Air Mixtures*

THE above table gives the approximate limits of flammability of gasses when admixed with air at ordinary temperatures and approximately atmospheric pressure. The list includes those gases found in sewers and at sewage treatment plants. The figures represent % by volume of the respetcive gasses in the air-gas mixture. The "Lower Limit" is that below which explosions *will not* occur; the "Upper Limit" is that below which flame propogation *will* be experienced, if not explosion; and above which the ratio of oxygen to gas is not sufficient to support burning or flame propogation in a closed tube or vessel.

	Lower Limit By Volume	Higher Limit By Volume
Ammonia	14.8	79.0
Methane (static)	4.3	14.0
Methane (turbulent)	5.0	15.0
Hydrogen	4.1	74.0
Hydrogen Sulphide	4.3	46.0
Carbon Monoxide	12.5	74.0
Water Gas	9.0	55.0
Natural Gas	4.8	13.5
Illuminating Gas	5.3	31.0
Blast Furnace Gas	35-37	65.0
Methane and Hydrogen Sulphine	4.1	71.5
Methane and Nitrogen	5.8	12.8

*Courtesy of The Vapor Recovery Systems Co.

P.F.T. Pacific Flush-Tank Co.

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NEW YORK CHARLOTTE, N.C.

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At army and naval establishments, ordnance plants and war housing projects, P.F.T. equipment is helping to maintain the health of America's armed forces and war workers.

P.F.T. Floating Covers

Accelerate the digestion process, eliminate odors and safely collect gas for heating and power purposes. Available in any practical shape for single or two-stage sludge digestion. Described in Catalog 232.

P.F.T. equipment for the boiler room includes flame traps, waste gas burners, drip traps and pressure indicating gages. Bulletin 121-A.

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Provide a practical, efficient unit for dosing sewage to filter medium, in minimum area and with minimum piping. Operate at minimum head, frequently eliminating pumping. Features include patented spreader jets that assure full, even coverage of the filter bed; triple valves and a positive mercury seal. Bulletin No. 213.

P.F.T. Sprinkling Filters

P.F.T. has available several efficient types of circular spray sewage nozzles for application to the risers in sprinkling filter beds. Easy to install and clean. Designed to minimize clogging. Detailed in Data Book No. 130.

P.F.T. Clarifiers

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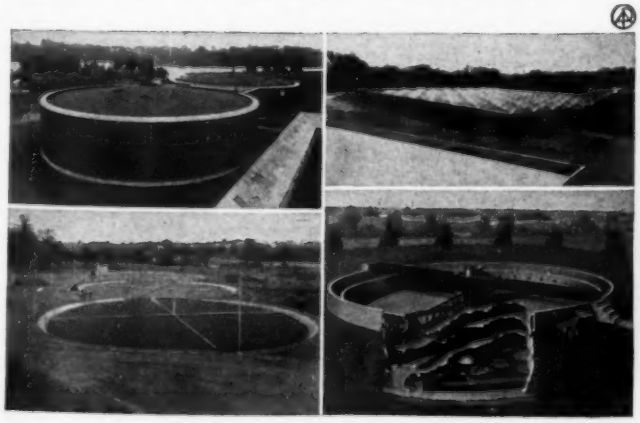

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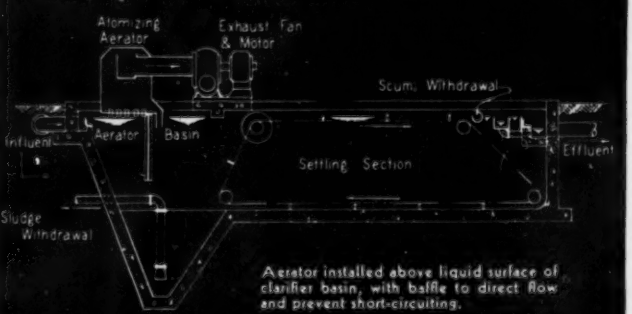
Consists essentially of a chamber to which a vacuum of approximately 3" of water is applied by an exhaust fan. This aerator circulates and intimately mixes atomized liquid and solids with a large volume of free air. A greater surface area of the liquid and solids is exposed to the air, and more oxygen is entrained and retained, as compared with conventional practice. For pre-aeration of sewage and grease removal, the aerator is mounted in a small section of the primary clarifier. Described in Bulletin 140

P.F.T. Supernatant Liquor Treater

This equipment comprises an aerator settling tank unit, which returns to the plant a treated effluent which will not cause operating difficulties. Ask for Bulletin 142.

P.F.T. Pre-Treater for Laundry and Related Trades Wastes

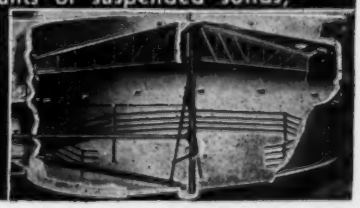
Consists of a combination aerator-settler unit, which reduces grease content, suspended solids and B.O.D. Ask for Bulletin 141.



Aerator installed above liquid surface of clarifier basin, with baffle to direct flow and prevent short-circuiting.

P.F.T. Supernatant Selector

A positive means of removing the best supernatant liquor at a slow, continuous rate from any type of digestion tank, regardless of where the supernatant is located in the tank. Consists of a tubular structure, with slots of proper size to hold back liquid containing large amounts of suspended solids; resulting in withdrawal of the best available supernatant. Ask for Bulletin 143.



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Turn Sewage Disposal Costs Into Profits While Increasing America's Food Production

Royer "Jr." (Gasoline Engine)

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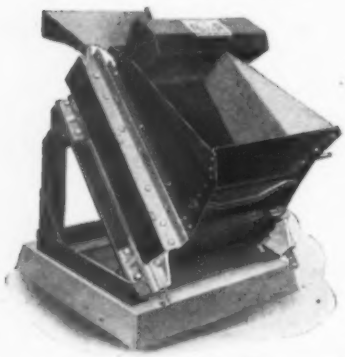
Model "NSH"



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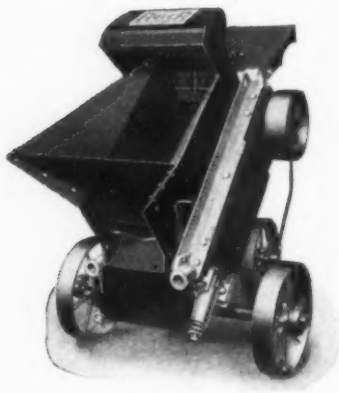

Model "NSM-2"

The practice of burning or burying sewage sludge was wasteful enough in peace-time, and is much more so today. America must have more fertilizer if we are to produce the greatly increased volume of food required to feed millions of people overseas as well as our own population. Production curtailment of imported and domestic fertilizing materials makes it essential that every available source be utilized to the utmost. Sewage sludge has, when properly prepared, the properties of a most productive fertilizer.

Hundreds of sewage disposal plants are selling fertilizer at a substantial profit or are utilizing it at parks, municipal golf courses and institutional grounds, and have eliminated the cost of sludge disposal by means of the **Royer Sludge Disintegrator.**

Sludge from the drying beds is shoveled into the hopper of this rugged, inexpensive machine, which thoroughly shreds, mixes, aerates and further dries it. The Royer discharges an excellent fertilizer onto pile or truck, suitable for truck farms, under-glass growing and Victory gardens. The Royer is also used in city parks for mixing lawn top dressing.

The Royer soon pays for itself at a sewage disposal plant. It is available in twelve stationary and portable models; in sizes for every plant; electric, gasoline engine or belt-to-tractor driven. Over 5,000 Royers are in use the world over.

Write for new "Sewage Sludge Utilization Datalog."

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THE ROYER

FERTILIZER AND FERTILITY

Values of Sewage Sludge

DR. WILLEM RUDOLFS
Chief, Dept. of Water and Sewage Research
N. J. Agricultural Experiment Station
New Brunswick, N. J.

THE use of various types of sewage sludge as sub-grade fertilizer or soil builders has been advocated for many years. Enthusiasm to use this by-product of sewage treatment has come mainly from the layman, but soil technologists and soil scientists continue to wonder why sludge is not returned to the soil for its plant food and fertility value. (Note that a distinction is made between plant food content and fertility value.) Many farmers, gardeners, florists and green-keepers have tried the material, but frequently have stopped after some years.

Sanitary engineers in general have looked at the sludge problem as a question of destruction of noxious matters rather than conservation of values. Sewage plant operators have tried to stimulate its use. There is an increasing tendency to find ways and means to utilize sludge, principally as a fertilizer filler or for soil improvement through direct application.

An inquiry to determine why the material is not used on a larger scale, especially from smaller plants, or why the use has been discontinued, seems to indicate several reasons which can be summarized as follows: (1) insufficient knowledge of the value, (2) improper use of the material or insufficient preparation, (3) excessive claims made by the seller, or (4) lack of interest by the seller.

From a hygienic standpoint there is *no problem* if the sludge is used in a proper manner. A rather extensive inquiry made to determine whether ill-effects have been observed on animals or human beings, shows that where land disposal has been practiced for many years no disease or epidemics have occurred. This is probably due to the fact that users of large quantities of sludge have taken proper precautions. As a rule fresh sludge has been used only on forage crops and plowed under after application. Heat dried activated sludge and heat dried digested sludge appear to be safe for any reasonable use in agriculture, horticulture or floriculture, while well digested air dried sludge appears to be as safe as manures.

What Is the True Value of Sludge?

Determinations of the values in sewage sludges have chiefly been a matter of testing for the principal fertilizer ingredients (nitrogen, phosphorus and potash), while sometimes the organic matter content is taken into consideration. Users of sludge for agricultural or horticultural purposes have repeatedly called attention to the fact that the results obtained could not be entirely accounted for by the mineral or plant food constituents. The better results have been variously explained on the basis of: (1) the organic matter content of the sludge results in an increased moisture holding capacity of the soil, preventing retardation of growth or wilting during dry weather; (2) an improvement in the soil structure, especially in clay, allowing more air to enter and subsequently a stimulation of oxidation or organic matter by the soil organisms; (3) introduction of large numbers of bacteria and protozoa, resulting in a speeding up of decomposition, the introduction of micro-organisms, such as molds, into the soil, making the nutrients more available for the plants; (4) introduction of certain minerals needed for plant growth; absence of weed seeds, which may utilize the available plant food.

On the other side of the picture is the discontinuance of the use of sludge after several years on account of plant injury. The reasons advanced for plant injury have been mainly: introduction of poisons in the soil which were present in the sludge (certain industrial wastes); high grease content resulting in water logging and production of organic acids; burning of plants resulting from acidic decomposition products which make the soil acid.

Sludge Constituents—Major and Minor

Until a relatively short time ago it was assumed that only ten chemical elements (nitrogen, phosphorus, sulfur, calcium, magnesium, potassium, iron, carbon, hydrogen and oxygen) were indispensable for the growth of higher plants. Many other elements, if found effective, were regarded as plant stimulants. In 1914 Prof. Mazé at the Pasteur Institute in Paris, showed that other elements were necessary. Not much attention was paid until in 1923, when Miss Warrington at the Rothamsted Experiment Station in England found that boron was essential for beans and several other plants. Only during the last few years has it been found that a number of plants can not complete their growth cycle without minute quantities of boron, copper, zinc, manganese, possibly molybdenum and several others. These "minor," or "accessory," or "micro-nutrient" elements have a remarkable effect on various phases of plant growth. Iron, for instance, plays a role in oxidation, copper has been reported as

Preparation and Conditioning an Important Consideration in Marketing
Compare the handleability and saleableness of the lumpy product on the left as removed from the drying beds, and the uniformly granulated and aerated product turned out by a well known sludge disintegrator

essential in certain oxidase systems; manganese is essential to respiration and to nitrate reduction in plants; zinc may be important in the change of carbonic acid to water and CO_2; certain metal deficiencies produce chlorosis of varied types of green plants.

A compilation of the chemical composition of sludges, including the main fertilizer constituents and the "minor" elements, is given in Table I. For comparison it should be kept in mind that the average fertilizer ingredients of barnyard manures are about 2 per cent nitrogen, 1 per cent phosphorus (P_2O_5) and 1.5 per cent potash (K_2O). It is evident that in addition to the main fertilizer ingredients, small quantities of "minor" elements are present in the sludge which may play an important role in plant growth. The quantities of minor elements are relatively small, so that danger of poisoning the soil is absent. The quantities of lime salts present in the sludge varies with the hardness of the water supplies and the manner of sludge treatment. The amount of lime salts expressed as (CaO) may be as low as 2 per cent and as high as 12 per cent on a dry basis.

A Potato Crop—With and Without

From the same area, in a field side by side, potatoes on left were fertilized with 400 lbs./acre of Toledo's air-dried digested primary sludge, marketed under the name "Tol-e-Gro." The yield was just 200 per cent more than the pile on right not fertilized.

TABLE I

Average Chemical Constituents of Sewage Solids and Sludges*

Element	Fresh Solids	Digested Sludge	Activated Sludge
Total Nitrogen (N)	4.50*	2.25*	6.20*
Phosphoric (P_2O_5)	2.25	1.50	2.50
Potash (K_2O)	0.50	0.50	0.75
Silica (SiO_2)	13.80	27.60	8.50
Iron (Fe_2O_3)	3.20	6.00	7.20
Aluminum (Al_2O_3)	2.10	4.30	3.20
Calcium (CaO)	2.70	5.70	1.70
Magnesium (MgO)	0.60	1.00	1.40
Manganese (MnO)	0.02	0.04	0.03
Sodium (Na_2O)	0.80	1.50	1.00
Titanium (TiO_2)	0.06	0.10	0.08
Copper (CuO)	0.02	0.05	0.05
Barium (BaO)	0.05	0.10	0.06
Zinc (ZnO)	0.01	0.04	0.03
Lead (PbO)	0.10	0.20	0.20
Nickel (NiO)	...	...	0.005
Cobalt (CoO)	0.0002	...	0.0002
Sulfur (So_3)	1.2	2.5	2.90
Chlorides (Cl)	0.50	0.50	0.50
Chromium (Cr_2O_3)	...	...	0.20
Arsenic (As_2O_3)	trace	trace	0.013
Boron (Br_2O_3)	...	...	0.0115
Iodine (I)	...	...	0.001

*All figures being % of each ingredient on the dry basis.

Humus Value

As a soil builder the humus content of sludge is less than that of barn-yard manure, because the ash content is greater, but still is of considerable value in sandy and heavy clay soils.

The crude fiber (cellulose, lignin, etc.), being complex insoluble carbohydrates, resist bacterial decomposition and remain longer in the soil (TableII). Most of the so-called total organic matter gradually disappears, but is of importance from the standpoint of humus accumulation and moisture holding capacity of the soil. Soils which retain a higher moisture content, usually support a greater variety of plants and allow the plants to continue their growth even during dry spells.

Fats and greases are important chiefly because they make the sludge lump and interfere with the desirable uniform distribution of the sludge. Also, because grease decomposition produces acidic compounds, resulting in acidic soils. It is our experience that most of the injurious effects that may be chargeable to sludge application for a number of years are due to the accumulation of acids in the soil. The first few years these acids have a tendency to make insoluble plant foods present in the soil more available; hence, produce better results than might be expected from the sludge alone. After a few years the available insoluble plant food has been reduced and the soil becomes more and more acid. Certain plants, which desire a neutral or only slightly acidic soil, are retarded in their growth and finally are injured by the accumulated acidity. The simple application of agricultural lime (carbonate of lime) neutralizes this acidity. For best results in the long run, a judicious lime application every 3 or 4 years prevents a good deal of trouble. The fact that this simple remedy often has been overlooked accounts for reluctance of farmers and greenhouse growers to use sludge after a few years' trial.

Growth-Promoting Substances

Increasingly, it is recognized that plants do not synthesize vitamins or their precursors as a philanthropic act for the benefit of animal or man. These substances have a function in the plant itself. The substances are generally classified as growth-promoting substances, since they may induce root development, stem elongation, cell swelling, ripening of fruit, stimulate germination and flowering, and produce other responses. Farm yard manure and decaying vegetable matter have been shown to contain various growth-promoting substances. Tests made for the presence of some of these substances in sewage sludges are summarized in Table III.

The quantities of growth-promoting substances required to affect the growth of plants are extremely small. Comparatively large applications of artificially produced compounds may even cause injury or retardation. Indole and skatole derivatives appear to be among the most effective growth-promoting substances. Indole and skatole, as well as butyric, acetic and propionic acids, are produced during decomposition of sludge and can be expected to be present. The presence of various growth-promoting substances give to sludges a higher *fertility value* than indicated by a mere chemical analysis, which reveals only the principal *fertilizer ingredients.*

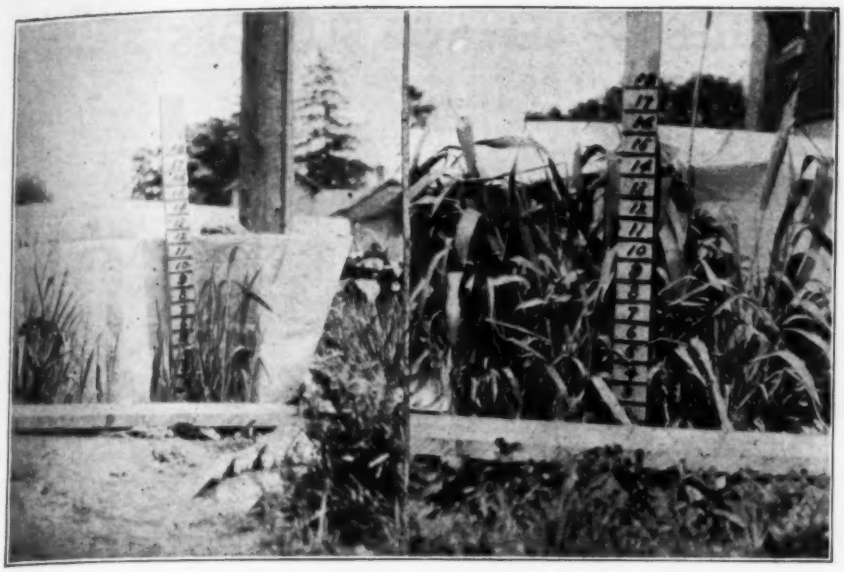
Practicing farmers have maintained for years that mineral fertilizers "burn out" the soil. What is meant is that mineral fertilizers stimulate the destruction of organic matter, making the plant food, plant stimulants and hormones available in greater abundance. This results in increased crop yields, but also gradually reduces the stored-up fertility of the soil. Thereby,

TABLE II

Composition of Sludges

Constituent*	Fresh Solids	Digested Sludge	Activated Sludge
Organic Matter	60-80*	45-60*	65-75*
Total Ash	20-40	40-55	25-38
Insoluble Ash	17-35	35-50	22-30
Pentosans	1.0	1.50	2.10
Grease and Fat (Ether)	7-35	3.5-17.0	5.0-12.0
Hemicelluloses	3.2	1.6	.....
Cellulose	3.8	0.6	7.0†
Lignin	5.8	8.4	.....
Protein	22-28	16-21	37.5

*All figures being % of each constituent on the dry basis.
†Includes lignin, etc.



A Small Grain Demonstration
In this instance, a 40-day growth of barley

TABLE III
Presence of Growth Promoting Substances in Sludges
(Relative Amounts of Single Substances)

Substance	Fresh Solids	Digested Sludge	Activated Sludge
Skatole, p.p.m.	1.2 -7.8	traces	none to traces
Indole, p.p.m.	0.12-7.0	0.5-1.0	0.0-0.05
Ascortic acid (Vitamin C)	++++	++++	++++
Carotene	+++	++	+
Tryptophane (free)	++++	+	++
(combined)	++++	++	+++
Tyrosine (free)	++++	+	++
(combined)	++++	++	+++
Phenyl compds.*	++++	++	++
Naphthyl compds.†	—	—	—

*As benzoic acid; † as ∝-naphthol.

the soil becomes poorer. The value of farmyard manure is in replenishing the organic matter, "minor" elements and growth-promoting substances. Its application is of importance, therefore, in making the soil gradually richer. A similar function can be ascribed to sewage sludge. Since sewage sludge contains only relatively small amounts of the principal fertilizer ingredients crop yield cannot be as great as from mineral fertilizers; but, like other improved animal manures, it improves the soil and will continue to do so if acidity is checked by lime applications.

Sludge Enrichment or Sludge Filler

The addition of mineral fertilizers to enrich sludge results in a more complete product. Not only are the necessary major plant foods present, but the required "minor" elements and growth-promoting substances are available. This combination produces a balanced fertilizer and, also, a soil builder. This balanced product gives higher crop yields without loss of soil fertility. Such a balanced product is of especial value for sandy and clay soils. The response of rich loamy or peaty soils to this balanced product should be less and it explains partly why experiments conducted with various crops in different soils may appear to be contradictory.

The amount of organic matter present is of importance, because of its favorable effect on the absorption capacity of the soil, and is of further interest because it is the carrier for organic nitrogen, which aids bacterial decomposition and becomes available to the plant when needed.

Crops and Plants Benefited

A compilation of plot experiment results and actual practice of crops and plants which have been benefited from sludge applications (Table IV) indicate that a number of grasses, root and leaf crops, trees and shrubs respond to sludge. The list is incomplete, because only those plants have been included where sludge was of *definite* value. Cases where the value was doubtful or contradictory have been disregarded. Sludge has been found to be of particular value on lawns and greens. It does not cause "burning," but small applications of lime are necessary from time to time.

TABLE IV
Crops and Plants Which Have Benefited from Sludge Applications

Truck crops—
- Squash
- Tomatoes
- Turnips
- Pumpkins
- Beets
- Carrots
- Radishes
- Parsnips
- Onions
- String beans
- Lima beans
- Lettuce
- Spinach
- Sweet corn
- Cabbage
- (and others)

Field crops and fruits—
- Corn
- Wheat
- Rye
- Barley
- Turnips
- Grass
- Beets
- Mustard
- Potatoes
- Tobacco
- Cotton
- Apples
- Citrus fruits
- Strawberries

Flowers—
- Roses
- Carnations
- (Many annual flowers respond to sludge, in some cases leaf growth is more stimulated than is flowering.)

Trees and shrubs—
- Maple
- Ash
- Birch
- Chestnut
- Prunus
- Cornus
- Jasminium
- Hydrangea
- Berberis
- Spirea
- Daphne
- Cotoneaster
- Taxus
- Several broad leaf evergreens

The amount of sludge applied varies with the crop. For field crops the application varies from 6 to 10 tons per acre, but additions up to 40 tons per acre have produced good results. A number of nursery men have reported good results with young trees and shrubs with sludge used in a manner and in quantities such as would be used if the material were barn-yard manure.

Over-All Value

The *fertility* values together with the *fertilizer* value of sewage sludges may be summarized in general as follows:

In addition to relatively small amounts of the principal fertilizer ingredients, sewage sludge contains "minor" chemical elements and growth-promoting substances essential and necessary for proper plant growth. It prevents depletion of humus and is capable of increasing the fertility of the soil. It improves the soil structure in general and increases the water holding capacity of sandy soil in particular. The value of sludge is not the same for all soils, neither is it the same for all crops. Except for growth observations there is no adequate measuring-stick for revealing the over-all value of sewage sludges as soil improvers and growth promoters—in short, their fertility values as contrasted to their limited worth as fertilizers, based on the chemist's analysis alone.

THOSE PLUS VALUES OF SEWAGE SLUDGES — IN SHORT, "FERTILITY"

(*Well Demonstrated in 13 Years of California Experience*)

Excerpts from a Discussion

By A. M. RAWN
Chief Engineer and General Manager
Los Angeles Sanitation Districts
Editorial Associate, WATER WORKS AND SEWERAGE

IT has long been recognized by those who have used, or observed the use of sewage sludge as a fertilizer that the value of the sludge in that capacity appears greater than the sum total of its fertilizing constituents, and that its influence in crop culture goes over and beyond anything which the customary analyses as applied to other fertilizers may indicate. Although there is nothing mysterious about these somewhat obscure factors they have not been generally recognized in their true form heretofore. Therefore, the story by Doctor Willen Rudolfs, in the December issue of WATER WORKS & SEWERAGE, in which he separates out values (fertilizer), which react to laboratory analysis, and those (fertility) which are determinable only by observing plant reaction to the fertilizer, is timely and important and should have a beneficial effect upon the future use of sludge.

Some California Experiences

In Southern California there are three sewage treatment plants, each producing a type or grade of sewage fertilizer quite different in composition and characteristics; nevertheless all are find-

A Further Testimonial for Sewage Sludge.

Two Valencia groves that are thriving and two adjacent plantings of identical age that are not. The two upper views are but 200 ft. apart. The only known difference in treatment is that the grove on the right has been fertilized with shredded digested sludge cake and kiln dried fine-screenings for the past several years. The lower views are of two groves separated only by a road. That on left has had no fertilizing; that on right has been fertilized solely with Los Angeles fine screenings. These groves, of the same stock, were planted simultaneously. When considering various experiences, and these long term results with digested sludge, one is convinced that it possesses a plus value which the expressive and inclusive term "Fertility Value" most aptly defines.

ing a ready acceptance in the culture of citrus groves and to some extent in other crops. Each appears to have characteristics, not measurable by laboratory yardsticks, which give them the extra values about which Doctor Rudolfs speaks.

The Pasadena Tri-cities sewage disposal plant has successfully pioneered the sale of dried activated sludge. Not only the orange grower but the fertilizer company appears to have accepted "Nitroganic" as more than an ordinary crop producer. It has been used for years successfully as the *sole* fertilizer on many extensive orange groves.

The joint disposal plant of the Los Angeles County Sanitation Districts is a large producer of dried digested primary sludge, a material containing between 2 and 3 per cent nitrogen and a comparatively low content of phosphoric acid and potash. Its organic content ranges from 50 to 55 per cent. This material is sold to a fertilizer agency on the open drying beds at a rate which yields the districts about $2 per dry ton. The buyer stands the expense of removing the sludge cake from the beds. It is macerated and sold in bulk to orange growers for about $7.00 per ton at 40 per cent moisture. The material bears the trade name "Nitrohumus" and is advertised as an organic sewage fertilizer. (Figured on a dry basis the price of $7.00 per ton in bulk for a digested primary sludge is worthy of note.—Ed.)

What Makes the Product Worth the Price?

"Nitrohumus" has been on the market for thirteen years in one form or another, and the pioneering days with it seem to be over. It has qualities for promoting growth which render it highly desirable. In addition to those mentioned by Doctor Rudolfs, it does two additional jobs, one of which may be readily understood—the other being not so clear. (1) It greatly stimulates growth and propagation of angle worms in the soil, such being recognized as highly beneficial in tree culture; (2) it appears to put inorganic fertilizers "to work" in soils in which they otherwise seem sluggish or ineffective. The proof of the latter has been manifested in citrus groves where sewage fertilizer has succeeded admirably, and where inorganic fertilizer previously applied have failed; and (3) it has stimulated growth much more than might be accounted for by the quantity of sludge applied in terms of commercial inorganic fertilizer values.

Dried Screenings

The third material which is produced in this area is the dried fine screenings at the Hyperion sewage disposal plant of the City of Los Angeles. This material, undigested, is dried in a rotary kiln and hauled thence to the orange groves for direct application. One grove in particular which is illustrated in this narrative, has been fertilized with nothing else than these fine screenings. The trees are planted in a sandy, reasonably sterile soil, and an excellent opportunity is offered for comparison with an unfertilized grove directly across the road. The difference between the two is indicative of the highly beneficial character of this type of fertilizer which, upon laboratory analysis would appear to be quite worthess.

Some Demonstrations

The effect of digested sludge upon lawn development is extraordinary. One of the tricks in advertising in this area is to request the prospective customer to let the salesman sprinkle a little of the fertilizer on the front lawn. The agent then writes the name of the fertilizer on the grass in fertilizer; asks the prospective customer to water the lawn a couple of times, with the result that in a week or ten days the name of the sludge is written in bright green across the yard. This very effective method of demonstrating the fertilier's ability has made many sales to a large number of permanent customers.

Commercial growers of iris, dahlias, gladiolas, pansies and marigold, are among a long list of repeat customers using digested sewage sludge for fertilizer. Dairy manure in this area is now selling for $1.50 per ton, delivered, roadside. This is the commercial variety containing about 1¼ per cent nitrogen. Digested sewage sludge, roadside delivery, is selling for $7 per ton. The difference in selling price is not indicative of high pressure salesmanship; to the contrary—it portrays better than any other factor the difference in value and is excellent proof of the fertility value of the product.

"DRY CLEANING" AIR DIFFUSER PLATES

By A. M. RAWN

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EVERY once in a while someone does something that makes one stop and wonder why it has never been done before. Or, if ever done, why he has not heard of it.

Maybe you have been in Southern California when, due to "unusual weather conditions" the winter temperature drops below freezing and the citrus growers start the orchard smudge-pots to warm up the whole outdoors and keep the crops from freezing. If you have, you may recollect that upon such occasions the air in the orchard area is so filled with thick, oily smoke that one cannot see a hundred feet. This winter has been such a one and for a number of days early this month (January) millions of gallons of oil have been burned in the smudge-pots.

Now this may not seem to have anything to do with sewage disposal, but strange enough it does have.

The city of Ontario lies right in the heart of the citrus grove area and, in consequence, was encompassed in a dense smoke fog for some time. During this period the operator of the Ontario activated sludge plant noticed that the pressure on the air lines was steadily increasing at the blowers. Attributing it to the oily carbon in the air, as most likely responsible for the clogging of the diffuser plates, he made every effort to cleanse the air by straining it through several thicknesses of cloth over the air inlet to the blowers. The cloths were changed frequently but to no avail. And, pressures at the blower mounted from 5 to 7½ pounds over night.

Obviously the diffuser plates, which had operated for more than a year with no building up of pressure, had to be cleaned. The finely divided carbon and oil in the smoke had doubtless spread quite uniformly through the plate pores. The orthodox manner of cleaning would have been to remove the plates and clean them up with a solvent and, if not successful, burn out the volatile materials, possibly. The city engineer had other ideas, however, and instead of bringing the plates to the solvent the solvent was taken to the plates. A scheme for injecting the solvent into the air stream from the blowers was put into operation.

What was actually done was to slowly pump "Aviation" grade of gasoline into the airline and beyond the blower. Two gallons of gasoline was fed into the pipe slowly during a 24-hour period. It did the job all right, because during this period pressures dropped back to normal and the trouble was completely cured. So far, there has been no injurious effect upon the quality of the plant effluent or the behavior of the sludge.

This struck the writer as being a most unique method of overcoming a serious difficulty. Mr. Austin Burt, Ontario's city engineer was "the brains" behind this "solvent-solved situation"; and H. M. Ely, as chief operator of the plant, was "the brawn."

In his latest advice to the writer the "inventor" of diffuser dry cleaning states: "We have had to apply our gasoline remedy to the diffuser plates *seven* different times during the more than two weeks of smudge conditions. Each time the pressure was brought back to normal, and thus far we have been unable to detect any serious consequences in the operation of the plant. Altogether, we used seven and one-half gallons of aviation gasoline at the total cost of only $1.16 and feel pretty good at saving the trouble and cost of emptying the tanks, removing and cleaning the plates."

SERVICING OF POROUS AIR DIFFUSERS

By FRANK C. ROE

Director of Sanitary Sales, The Carborundum Co., Niagara Falls, N. Y.

To maintain the high efficiency of porous diffuser plates and tubes of the type used for aeration in sewage and water treatment plants, their operation should be checked regularly. Partial clogging of the porous structure may occur for a number of reasons, thereby decreasing the effectiveness and increasing the cost of aeration.

The writer and his company have made a study of the various methods of servicing diffusers necessary to maintain their efficiency for a reasonable life.

The most immediate and positive indication of obstruction within the diffuser structure is an increase of compressor or blower pressure necessary to supply a given quantity of air. Visual examination of the aeration tank or tanks will also disclose non-uniformity of diffusion which may be due to a partially clogged condition. This is a practical determination but not so conclusive as the first.

Diffusers may become clogged on either the air side or on the liquor side; that is, on the top or bottom of plates and on the outside or inside of tubes. Both classes of clogging may be experienced simultaneously, but are avoidable to a great extent.

Liquor Side Clogging

1. *Suspended Solids*: Perhaps the most common type of clogging is caused by interruption of aeration during which the solids in water, sewage, sludge or mixed liquor settle and the water content filters through the diffusers into the air duct. Most of the solids in suspension are intercepted at the diffuser surface, but a definite proportion, depending on the pore size, will enter the top 1/16 to ⅛ inch of the structure. When aeration is resumed all of these particles will not be blown out of the structure and cumulative clogging results.

Maintenance of continuous air delivery, at least to some degree, is the positive way to preclude this trouble. Temporary cessation of the air supply is not impossible with modern equipment, but the usual auxiliary blowers with standby power units and inexpensive automatic control equipment will largely eliminate shutdowns.

Care should also be taken not to over-design in the matter of diffuser area. Not less than one cubic foot of air per minute should normally be discharged per square foot of diffuser area. Insuring a higher rate, so as to maintain good air velocity through the pores as well as uniformity of diffusion from the entire diffuser area, is better practice still.

2. *Organic Growth*: Another form of liquor side clogging is growth of bacterial and protozoa life in the uppermost portion of the porous structure. This may be attributed, at least partially, to non-uniformity of diffusion. All of the diffusers controlled by a single valve may not have similar permeability ratings, or the individual areas of any particular diffuser plate or tube may not be uniform one with another.

As suggested, it should be possible to avert clogging of this nature by careful installation and selection of plates or tubes. All units controlled by a single air valve should have a similar permeability rating within limits of 0.5 cu. ft. or less. Uniformity of individual diffusers depends upon precision and perfection in manufacturing.

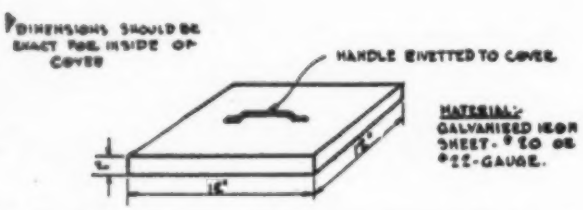

DIMENSIONS SHOULD BE EXACT FOR INSIDE OF COVER
HANDLE RIVETTED TO COVER
MATERIAL: GALVANIZED IRON SHEET. 20 OR 22-GAUGE.
15"

Plate Cover for Protecting Diffuser Plates During Setting

[*For an excellent discussion of "The Economics of Cleaning Air-Diffusion Media" see the magazine section of this issue.*]

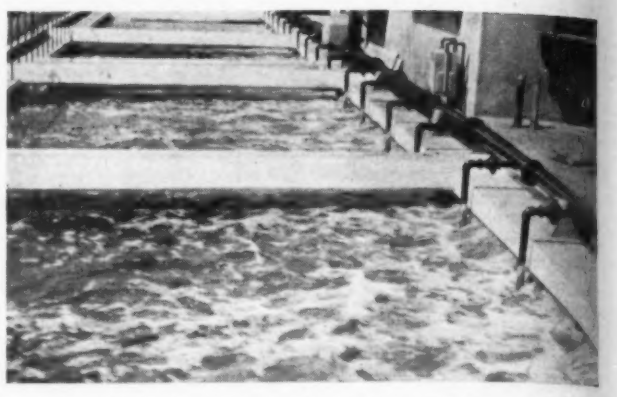


Plate 1—A Section of Aeration Tanks (Sewage Treatment Plant, Golden Gate Park, San Francisco), an Example of Uniform Diffusion

3. *Miscellaneous*: Very often protection from cement grout (or other material used to install plates), dirt, debris, etc., is not provided during installation or when tanks are empty, and appreciable surface clogging results. A plate cover (see sketch) should be used to shield plates from cementing materials during installation, and other protective measures should be observed when tanks are empty.

Air Side Clogging

1. *Dirt in Air*: Air containing a high quantity of soot or other impurities is a major source of clogging on the underside of diffuser plates or inside of diffuser tubes. Selection of effective air filters and care in locating the air intake are obvious preventatives.

The thought should be injected here that diffusers of higher permeability than the type used during the early days of sewage aeration are undoubtedly subject to less clogging of this nature because of relatively larger pores through which many of the fine suspended particles pass rather than stop. It is doubtful if the air bubbles released from higher permeability diffusers are very much larger than the bubbles discharged from the earlier low permeability grade of diffuser. The fact remains that higher permeability diffusers have not been less effective than those of lower ratings previously specified.

2. *Oil in Air*: Reciprocating compressors are now rarely used in sewage aeration, but the oil which they force through air lines is responsible for pronounced diffuser pore plugging. Fortunately, the low pressure required for sewage aeration permits the use of rotary blowers of the centrifugal or positive displacement type. If reciprocating units must be used for any reason, an oil trap or filter of some kind should be used between the compressors and the diffusers.

Certain types of primary air filters depend on the use of an oil for cleaning or renovating. In this operation it is recommended that a partial wash with a solvent be given after the oil treatment so that oil will not be blown free and carried through the diffusers.

3. *Air Pipe Rust or Scale*: It is generally recognized that cast iron pipe as a material for air lines is sufficiently resistant to corrosion from moisture to be considered to have almost an endless life. Genuine wrought iron is likewise considered satisfactory. Galvanized or sherardized steel pipe would be considered suitable for relative short periods of life, while ordinary black iron pipe or steel is not suitable.

In spite of the consideration given to this phase of air pipe design, there is evidence that some air side clogging is caused by iron oxide in the form of rust particles and scale.

There are economic considerations involved in preventing this source of clogging. Aluminum and copper pipe have been used

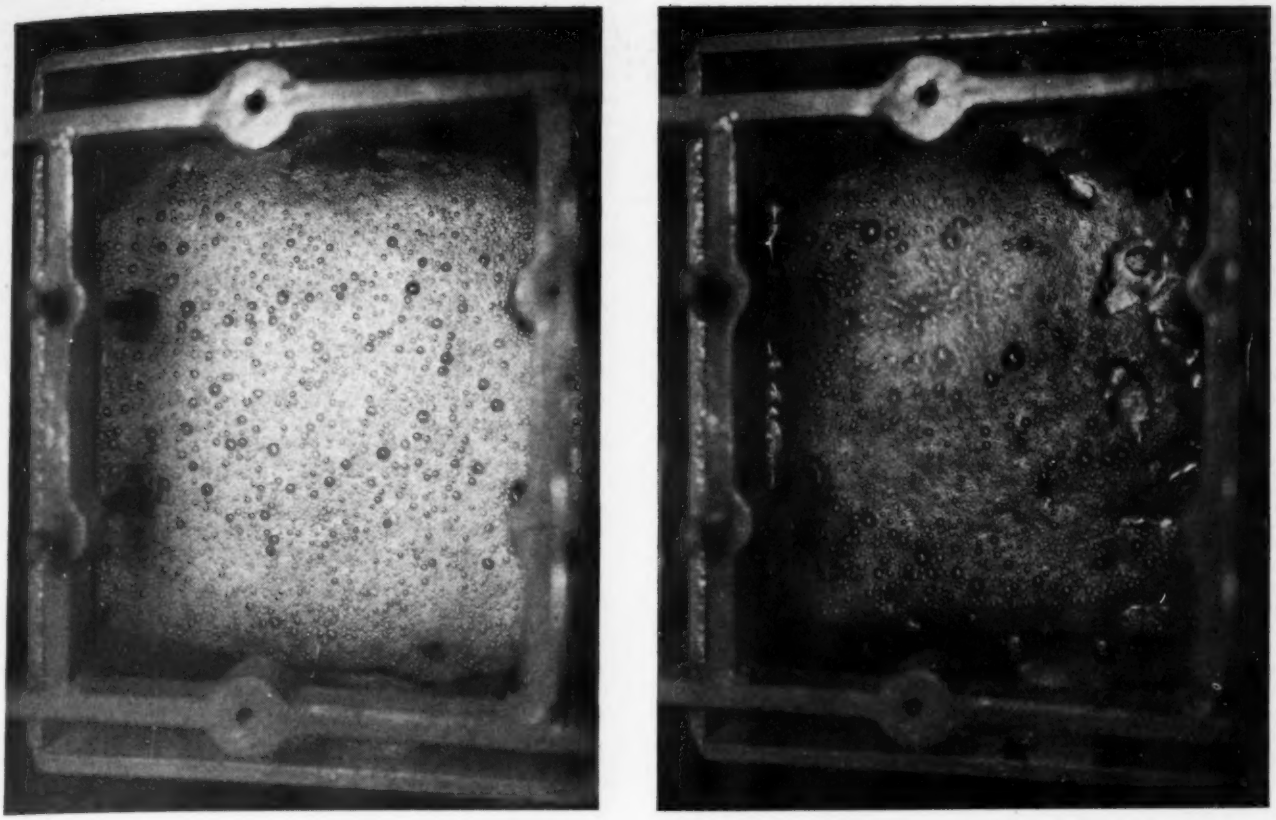


Plate 2—An Illustration of Good Uniformity of Diffusion on the Left; Poor Uniformity on the Right. (Photographs Taken Looking Down on Diffusion Plates in Testing Apparatus)

for the smaller air lines and are recommended along with other types of corrosion resistant pipe. However, if the use of such pipe raises the installation cost appreciably it should be balanced against the estimated cost of diffuser servicing and replacement.

4. *Miscellaneous*: Air lines left in a dirty condition after installation can cause clogging of considerable magnitude. The remedy is obvious. Cast iron diffuser plate containers may cause the same difficulty as does iron piping, but to a lesser degree. Mr. William M. Piatt has avoided this possible source of trouble in designing containers for some of his plants in North Carolina, by using aluminum container linings. At other plants the entire plate holder is to be of aluminum.

Restoration of Diffuser Efficiencies

Because of the diversified types and degrees of clogging experienced in the 100-odd activated sludge plants in the country, it is natural to expect that there are many methods of cleaning in use. Lacking information on the subject, plant superintendents and operators have, more or less successfully, devised and developed individual methods of their own.

The writer's company, in addition to considerable experimental work in the research laboratories. has fostered a survey among those in charge of plants throughout the United States and Canada, believing that many practical methods of diffuser cleansing would come to light. The response to our inquiries and the cooperation received has been most gratifying and has made it possible to present the outline to follow. Some of the methods have been improved, amplified or supplemented as the result of certain research work which we have conducted.

Methods employed in diffuser cleaning can be divided into two general classes; viz., methods applicable to diffusers in place (suitable largely to liquor side clogging) and methods which are adaptable only to removed diffusers. Tubes are cleaned for the most part by the latter method because they may be quickly and easily removed. The methods to follow are not given in an order to indicate preference.

Cleaning Diffusers in Place

1. *Caustic Treatment*: Clean aeration tank and surface of diffusers thoroughly with hose stream and leave about ½ in. of clean water over plates, providing the slowest practical air diffusion during this period. Dissolve about 1/10 lb. commercial lye crystals over each square foot of plate and then shut off air. Allow solution to penetrate plate (10 to 15 minutes), add more clean water, and then turn air on a maximum rate. (Note: This method is chiefly applicable to removal of organic compounds.)

2. *Sand Blasting*: Dry plates thoroughly by draining containers completely and blowing out porous structure with air

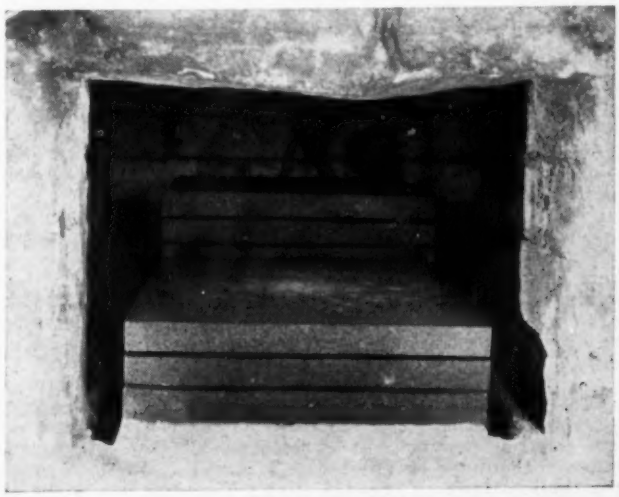


Plate 3—Diffuser Plates Stacked in Furnace for Burning-Out of Organic Matter. (More Clearance Between Plates Preferable; See Method 14)

applied at high rate. Sand blast plate surface with usual type of sand blast equipment, using "Blastite" Grain. Remove not more than 1/32 in. from surface, *maintaining maximum air discharge during the operation.* One minute or less is required to clean a plate by this method.

3. *Surface Spalling*: Dry plates by draining containers and blowing out porous structure with air at high rate. Apply oxy-acetylene flame with oxygen and gas at 10 lbs. pressure and gas at 5 lbs. pressure. The flame should be applied almost parallel to the diffuser surface, i. e., at as acute an angle as possible. Remove from .010 in. to .015 in. of diffuser surface. Sweep off and rub surface smooth with a Carborundum rubbing block. Sweep off particles again. Leave air on during entire operation.

4. *Burning Out Surface*: Dry plates by draining containers and blowing out porous structure with air at high rate. With air off, saturate each plate with one quart of alcohol and apply heat with blow torch. Dry and brush off surface.

5. *Acid Washing and Scrubbing*: Dry plates by draining containers and blowing out porous structure with air at high rate. With air off, apply a 30 per cent solution of hydrochloric (muriatic) acid to the surface liberally and allow same to penetrate somewhat before turning on air at a low rate. Scrub with a stiff brush, using more acid if necessary. Follow with a clean water wash and scrubbing with a wire brush, continuing air discharge at a somewhat higher rate. (Note: This method is chiefly applicable to removal of inorganic compounds.)

6. *Vacuum Cleaning*: This method has not been proven but was suggested by authorities at the Milwaukee Sewage Treatment Plant, where a trial was intended. A vacuum pump was to have been used with a suction inlet of small area which would be held closely against and moved back and forth across the diffuser surface to be cleaned.

7. *Rest*: Dry plates by draining containers and blowing out porous structure with air at high rate. Allow diffusers to rest while dry for a week or more. (Note: The theory of this treatment is that the change of conditions will cause the bacterial and protozoa growth in the porous structure to die.)

8. *Chlorine Treatment*:* Introduce a strong dose of chlorine into the branch air line leading to each diffuser assembly for several minutes during a low rate of air flow. Following by blowing out diffusers with the maximum possible rate of air flow. (Note: This method is chiefly applicable to removal of organic compounds and carbonates.)

9. *Steam Backwashing*:* Dry diffusers by draining and blowing out porous structure with air at high rate. Introduce steam into the branch air line at 10 lbs. pressure and scrub diffuser surface simultaneously with a stiff brush.

10. *Water Backwashing*:* Introduce clean water into the branch air line under pressure of 15 to 20 lbs. per sq. in. Scrub diffuser surface simultaneously with a stiff brush.

Cleaning Removed Diffusers

11. *Acid Pickling*: Wash diffusers with water (use hose and brush). Set in a vertical position and allow to drain and dry as much as possible. Soak in 30 per cent solution of hydrochloric or nitric acid for four hours. Wash with water. (Note: Use Hydrochloric acid if it is desired to dissolve inorganic compounds and nitric acid if it is desired to oxidize organic compounds.)

12. *Caustic Treatment*: Place diffusers in vessel containing a 10 per cent solution of sodium hydroxide (lye) and boil for about one hour. Remove from this solution and wash thoroughly in boiling water. (Note: This method is only applicable to partial removal of organic compounds, chiefly fats, which are saponified by the caustic soda and then dissolved in hot water.)

13. *Sandblasting*: Dry diffusers thoroughly (preferably in an oven of some kind) and sandblast (Method 2) on either or both sides, as required. It is recommended that, where practicable, the diffuser be inserted in a container which will make it possible to force air through it at a high rate during the operation. This will eliminate any clogging by the dust created.

*Methods applicable to tubes or plates and of some benefit also in cleansing the air side of diffusers.

14. *Burning*: This method is applicable to diffusers of the fused crystalline alumina type. Place diffusers in a furnace or kiln in any convenient position, leaving a space of not less than ½ in. between units. Raise temperature gradually during 10 hours to about 1000 deg. Centigrade and then allow to cool gradually. The cycle should take at least 16 hours. Fuel of any kind is satisfactory, but care must be taken to avoid impingement of flame against diffuser surfaces. At Decatur, Ill., gas from sludge digestion was used.

Selection of Method

Every plant operates under conditions peculiar to itself, which will prove a factor in the ease or difficulty of diffuser servicing and the methods of cleaning which can be, or should be, used. One method may work satisfactorily in one place but be wholly unsatisfactory in another place or at another time.

In general, methods used on diffusers *in place* are not better than 75 per cent effective and range down to as low as 10 per cent where the clogging is almost wholly on the air side. Methods of cleaning removed diffusers are much more effective and are from 60 to 95 per cent effective. It is usually a combination of two or more methods which will produce the best result; because, any single method is not a cure-all.

The combination of causes and degree of clogging vary greatly and therefore it is not possible to give a rating of effectiveness to each method of restoration. It can be stated, however, that acid pickling of removed diffusers (Method 11) followed by burning in a furnace or kiln (Method 14) is 90 to 100 per cent effective, regardless of type or degree of pore plugging. This combination is therefore, recommended where serious clogging exists.

A simple improvised furnace can usually be built at a sewage plant to refire diffusers, other considerations being satisfactory. Where this work proves impracticable in the field, the writer's company will use its kilns at Niagara Falls for refiring when requested. Such arrangements would offer an added advantage in that refired diffusers can easily be retested and rated so that they may be properly re-installed thereafter.

The above suggests the consideration of providing a simple permeability testing apparatus at sewage treatment plants which would be useful in re-rating removed diffusers which have been cleaned at the plant. Even though original markings are retained, which is doubtful, all units will not respond equally to the cleaning method employed and will have a new permeability rating which should be determined when re-installation is made.

For acid pickling (Method 11) a wooden tub is satisfactory. The caustic treatment requires an iron kettle because of the boiling operation. Workmen should use precaution in these methods by wearing rubber gloves, aprons, etc. Tongs can be used to handle diffusers.

Where existing plate containers do not permit simple mechanical plate removal, a joint composed of sand in the bottom ½ in. and cement grout in the top, is recommended for setting plates in holders. This will save time and avoid plate breakage when removal becomes necessary. Plates so installed should be set with a lime mortar under the supporting edges to insure an even bearing.

Conclusion

The practice of regular servicing should be stressed if the diffusers in any plant are subject to a known source of clogging. If this is done, whether it is apparently needed or not, the permeability will be maintained indefinitely, in all probability, and one or more of the simple and least costly methods of revivification can be employed.

Because of the several potential sources of diffuser pore plugging which exist, and because many of these cause air side clogging, the use of plate containers which permit easy removal of plates is recommended. Ease of removal and replacement is one of the important advantages of diffuser *tubes* for smaller plants. In this connection the new "swing" diffuser and stationary diffuser equipment offered by the Chicago Pump Company is highly recommended.

Diffusers of high permeability are less subject to clogging because of larger pores. They operate on a slightly lower air pressure than low permeability diffusers. Because of these advantages, and the fact that effectiveness of aeration is not decreased (compared to that provided by low permeability diffusers), plates of a higher rating are recommended.

ENGINEERING DATA

CONVERSION FACTORS FOR ENGINEERS*

The word gallon, used in any conversion factor, designates the U. S. gallon. Likewise, the word ton designates a short ton, 2,000 pounds.

The figures 10^{-1}, 10^{-2}, 10^{-3}, etc., denote 0.1, 0.01, 0.001, etc., respectively.

The figures 10^{1}, 10^{2}, 10^{3}, etc., denote 10, 100, 1000, etc., respectively.

"Parts Per Million," (designated as p.p.m.), is always by weight. As used in the sanitary field, p.p.m. represents the number of pounds of dry solids contained in one million pounds of water. In this field, one part per million may be expressed as 8.345 pounds of dry solids to one million U. S. gallons of water.

Multiply	By	To Obtain
Acres	43,560	Square feet
"	4047	Square meters
Acre-feet	43,560	Cubic feet
" "	325,851	Gallons
" "	1233.49	Cubic meters
Atmospheres	29.92	Inches of mercury
"	33.90	Feet of water
"	76.0	Cms. of mercury
"	14.70	Lbs./sq. inch
Barrels cement	376	Pounds—cement
Bags or sacks-cement	94	Pounds— "
British Thermal Units	777.5	Foot-lbs.
" " "	3.927×10^{-4}	Horse-power-hrs.
" " "	2.928×10^{-4}	Kilowatt-hrs.
" " "	0.2520	Kilogram-calories
" " "	107.5	Kilogram-meters
B.T.U./min.	12.96	Foot-lbs./sec.
" "	0.02356	Horse-power
" "	0.01757	Kilowatts
Centimeters	0.3937	Inches
Centimeters of mercury	0.01316	Atmospheres
" " "	0.4461	Feet of water
" " "	27.85	Lbs./sq. ft.
" " "	0.1934	Lbs./sq. inch
Centimeters/second	1.969	Feet/min.
" "	0.03281	Feet/sec.
" "	0.6	Meters/min.
Cubic centimeters	3.531×10^{-5}	Cubic feet
" "	6.102×10^{-2}	Cubic inches
" "	2.642×10^{-4}	Gallons
" "	10^{-6}	Cubic meters
" "	10^{-3}	Liters
Cubic feet	7.48052	Gallons
" "	1728	Cubic inches
" "	0.03704	Cubic yards
" "	28.32	Liters
" "	2.832×10^{4}	Cubic cms.
" "	0.02832	Cubic meters
Cubic feet/second	0.646317	Million gals./day
" " "	448.831	Gallons/min.
Cubic inches	16.39	Cubic centimeters
" "	5.787×10^{-4}	Cubic feet
" "	1.639×10^{-5}	Cubic meters
" "	4.329×10^{-3}	Gallons
" "	1.639×10^{-2}	Liters
Cubic meters	35.31	Cubic feet
" "	1.308	Cubic yards
" "	264.2	Gallons
" "	10^{3}	Liters
Cubic yards	27	Cubic feet
" "	46.656	Cubic inches
" "	0.7646	Cubic meters
" "	202.0	Gallons
" "	764.6	Liters
Drams	27.34375	Grains
"	0.0625	Ounces
"	1.771845	Grams
Fathoms	6	Feet
Feet	30.48	Centimeters
"	0.3048	Meters
Feet of water	0.8826	Inches of mercury
" " "	0.4335	Lbs./sq. inch
" " "	62.43	Lbs./sq. ft.
" " "	0.02950	Atmospheres
" " "	304.8	Kgs./sq. meter
Feet/sec.	30.48	Centimeters/sec.
" "	18.29	Meters/min.
Foot-pounds	1.286×10^{-3}	British thermal units
" "	5.050×10^{-7}	Horse-power-hrs.
" "	0.1383	Kilogram-meters
" "	3.766×10^{-7}	Kilowatt-hrs.
Foot-pounds/min.	3.030×10^{-5}	Horse-power
" " "	2.260×10^{-5}	Kilowatts
Gallons	0.1337	Cubic feet
"	231	Cubic inches
"	3785	Cubic centimeters
"	3.785×10^{-3}	Cubic meters
"	3.785	Liters
Gallons, Imperial	1.200095	U. S. gallons
" U. S.	0.83267	Imperial gallons
Gallons water	8.3453	Pounds of water
Gallons/min.	2.228×10^{-3}	Cubic feet/sec.
" "	0.06308	Liters/sec.
" "	8.0208	Cu. ft./hr.
Grains (troy)	1	Grains (avoir.)
"	0.06480	Grams
Grains/U.S. gal.	17.118	Parts/million
" /U.S. gal.	142.86	Lbs./million gal.
" /Imp. gal.	14.254	Parts/million
Grams	15.43	Grains
"	0.03527	Ounces
"	980.7	Dynes
Grams/liter	58.417	Grains/gal.
" "	8.345	Pounds/1000 gals.
" "	1000	Parts/million
Hectares	2.471	Acres
Horse-power	42.44	B.T. Units/min.
" "	550	Foot-lbs./sec.
" "	0.7457	Kilowatts
Horse-power (boiler)	33,479	B.T.U./hr.
" " "	9.803	Kilowatts
Inches	2.540	Centimeters
Inches of mercury	1.133	Feet of water
" " "	0.4912	Lbs./sq. inch
" " "	0.03342	Atmospheres
" " "	345.3	Kgs./sq. meter
Inches of water	0.07355	Inches of mercury
" " "	0.03613	Lbs./sq. inch
Kilograms	2.205	Lbs.
Kilograms-calories/min.	51.43	Foot-pounds/sec.
" " "	0.09351	Horse-power
" "	0.06972	Kilowatts
Kgs./sq. meter	3.281×10^{-3}	Feet of water
" " "	1.422×10^{-3}	Lbs./sq. inch
Kilometers	3281	Feet
"	0.6214	Miles
Kilometers/hr.	0.9113	Feet/sec.
" "	27.78	Centimeters/sec.
Kilowatts	56.92	B.T. Units/min.
"	737.6	Foot-lbs./sec.
"	1.341	Horse-power
"	14.34	Kg.-calories/min.
Liters	0.2642	Gallons
"	61.02	Cubic inches
"	0.03531	Cubic feet
Meters	3.281	Feet
"	39.37	Inches
"	1.094	Yards
Miles	5280	Feet
"	1.609	Kilometers
Miles/min.	88	Feet/sec.
" "	1.609	Kilometers/min.
Milligrams/liter	1	Parts/million
Million gals./day	1.54723	Cubic ft./sec.
Miner's inches	1.5	Cubic ft./min.
Ounces	28.349527	Grams
"	437.5	Grains
"	0.9115	Ounces (troy)
Ounces (fluid)	1.805	Cubic inches
" "	29.57	Cubic cm.
Parts/million	8.345	Lbs./million gal.
" "	0.0584	Grains/U. S. gal.
" "	0.07016	Grains/Imp. gal.
Pounds	16	Ounces
"	7000	Grains
"	453.5924	Grams
"	1.21528	Pounds (troy)

*Selections from a booklet of—"Conversion Factors for Engineers"—distributed by The Dorr Co., New York City.

Multiply	By	To Obtain
Pounds of water	0.01602	Cubic feet
" " "	27.68	Cubic inches
" " "	0.1198	Gallons
Pounds/cubic foot	0.01602	Grams/cubic cm.
" " "	16.02	Kgs./cubic meter
" " "	5.787×10^{-4}	Lbs./cubic inch
Pounds/foot	1.488	Kgs./meter
Pounds/inch	178.6	Grams/cm.
Pounds/sq. foot	0.01602	Feet of water
" " "	4.883	Kgs./sq. meter
Pounds/sq. inch	2.307	Feet of water
" " "	2.036	Inches of mercury
" " "	0.06804	Atmospheres
" " "	703.1	Kgs./sq. meter
Quires	25	Sheets
Reams	500	Sheets
Square centimeters	0.1550	Square inches
" "	1.076×10^{-3}	Square feet
Square feet	144	Square inches
" "	0.09290	Square meters
" "	2.296×10^{-5}	Acres
Square inches	6.452	Square centimeters

Multiply	By	To Obtain
Square kilometers	247.1	Acres
" "	10.76×10^{6}	Square feet
" "	1.196×10^{6}	Square yards
Square meters	10.76	Square feet
"	1.196	Square yards
Square miles	640	Acres
" "	27.88×10^{6}	Square feet
" "	2.590	Square Kilometers
Square yards	9	Square feet
" "	0.8361	Square meters
" "	2.066×10^{-4}	Acres
Tons (long)	1016	Kilograms
" "	2240	Pounds
" "	1.12000	Tons (short)
Tons (metric)	10^{3}	Kilograms
" "	2205	Pounds
Tons (short)	2000	Pounds
" "	907.18486	Kilograms
Tons of water/24 hrs.	0.16643	Gallons/min.
Watts	0.05692	B.T.Units/min.
"	0.7376	Foot-pounds/sec.
"	1.341×10^{-3}	Horse-power
"	0.01434	Kg.-calories/min.
Yards	0.9144	Meters

Relative Carrying Capacities of Pipe Lines of Equal Smoothness

Prepared by Emil L. Neubling for the Reading Meter Repair Co.

Diameter of Pipes	⅛	¼	⅜	½	¾	1	1¼	1½	2	2½
26										348.81
24										285.55
22										229.20
20									316.23	181.02
18									243.00	139.10
16								371.60	181.02	103.62
15								316.23	154.05	88.18
14							419.80	266.13	129.64	74.21
12							285.55	181.02	88.18	50.48
10						316.23	181.02	114.76	55.90	32.00
9						243.00	139.10	88.18	42.96	24.65
8						371.60	181.02	103.62	65.69	32.00	18.32
7						266.13	129.64	74.21	47.05	22.92	13.12
6						181.02	88.18	50.48	32.00	15.59	8.92
5					316.23	114.76	55.90	32.00	20.29	9.88	5.66
4½					243.00	88.18	42.96	24.65	15.59	7.59	4.35
4				371.60	181.02	65.69	32.00	18.32	11.61	5.66	3.24
3½				266.13	129.64	47.05	22.92	13.12	8.32	4.05	2.32
3				181.02	88.18	32.00	15.59	8.92	5.66	2.76	1.58
2½			316.23	114.76	55.90	20.29	9.88	5.66	3.54	1.75	1.00
2			181.02	65.69	32.00	11.61	5.66	3.24	2.05	1.00	
1½			88.18	32.00	15.59	5.66	2.76	1.58	1.00		
1¼		316.23	55.90	20.29	9.88	3.59	1.75	1.00			
1		181.02	32.00	11.61	5.66	2.05	1.00				
¾		88.18	15.59	5.66	2.05	1.00					
½		32.00	5.66	2.05	1.00						
⅜		15.59	2.76	1.00							
¼		5.66	1.00								
⅛		1.00									

Diameter of Pipes	3	3½	4	4½	5	6	7	8	9	10
48			498.83	371.60	285.55	181.02	123.13	88.18	65.69	50.48
46			448.48	334.09	256.73	162.75	110.70	79.10	59.06	45.38
44			401.31	298.96	229.20	145.63	99.29	70.94	52.85	40.61
42			357.25	243.00	204.50	129.64	88.18	63.15	47.05	36.15
40			316.23	235.57	181.02	114.76	78.06	55.90	41.64	32.00
38		388.41	278.17	207.22	159.23	100.94	68.66	49.17	36.63	28.15
36		339.30	243.00	181.02	139.10	88.18	59.98	42.96	32.00	24.65
34		294.12	210.64	156.92	120.58	76.44	51.99	37.24	27.74	21.32
32		252.76	181.02	134.85	103.62	65.69	44.68	32.00	23.84	18.32
30	316.23	215.10	154.05	114.76	88.18	55.90	38.02	27.23	20.29	15.59
28	266.13	181.02	129.64	96.57	74.21	47.05	32.00	22.92	17.07	13.12
26	221.12	150.41	107.72	80.24	61.66	39.09	26.59	19.04	14.18	10.90
24	181.02	123.13	88.18	65.69	50.48	32.00	21.77	15.59	11.61	8.92
22	145.63	99.29	70.94	52.85	40.61	25.74	17.51	12.54	9.34	7.18
20	114.76	78.06	55.90	41.64	32.00	20.29	13.80	9.88	7.36	5.66
18	88.18	59.98	42.96	32.00	24.65	15.59	10.60	7.59	5.66	4.35
16	65.69	44.68	32.00	23.84	18.32	11.61	7.90	5.66	4.21	3.24
15	55.90	38.02	27.23	20.29	15.59	9.88	6.72	4.81	3.59	2.76
14	47.05	32.00	22.92	17.07	13.12	8.32	5.66	4.05	3.02	2.32
12	32.00	21.77	15.59	11.61	8.92	5.66	3.85	2.76	2.05	1.58
10	20.29	13.80	9.88	7.36	5.66	3.59	2.44	1.75	1.30	1.00
9	15.59	10.60	7.59	5.66	4.35	2.76	1.83	1.34	1.00	
8	11.61	7.90	5.66	4.21	3.24	2.05	1.40	1.00		
7	8.32	5.66	4.05	3.02	2.32	1.47	1.00			
6	5.66	3.85	2.76	2.05	1.58	1.00				
5	3.59	2.44	1.77	1.30	1.00					
4½	2.76	1.83	1.34	1.00						
4	2.05	1.40	1.00							
3½	1.47	1.00								
3	1.00									

Diameter of Pipes	12	14	15	16	18	20	22	24	26	28
48	32.00	21.77	18.32	15.59	11.61	8.92	7.03	5.66	4.63	3.85
46	28.77	19.57	16.47	14.02	10.44	8.02	6.32	5.09	4.16	3.46
44	25.74	17.51	14.71	12.54	9.34	7.18	5.66	4.55	3.73	3.10
42	22.92	15.59	13.12	11.16	8.32	6.39	5.04	4.05	3.32	2.76
40	20.29	13.80	11.61	9.88	7.36	5.66	4.46	3.59	2.94	2.44
38	17.84	12.14	10.21	8.69	6.48	4.98	3.92	3.15	2.58	2.17
36	15.59	10.60	8.92	7.59	5.66	4.35	3.43	2.76	2.26	1.83
34	13.51	9.19	7.74	6.58	4.90	3.77	2.97	2.39	1.96	1.62
32	11.61	7.90	6.65	5.66	4.21	3.24	2.55	2.05	1.68	1.40
30	9.88	6.72	5.66	4.81	3.59	2.76	2.17	1.75	1.43	1.19
28	8.32	5.66	4.76	4.05	3.02	2.32	1.83	1.47	1.20	1.00
26	6.91	4.70	3.96	3.37	2.51	1.93	1.52	1.22	1.00	
24	5.66	3.85	3.24	2.76	2.05	1.58	1.24	1.00		
22	4.55	3.10	2.61	2.22	1.65	1.27	1.00			
20	3.59	2.44	2.05	1.75	1.30	1.00				
18	2.76	1.83	1.58	1.34	1.00					
16	2.05	1.40	1.18	1.00						
15	1.75	1.19	1.00							
14	1.47	1.00								
12	1.00									

Diameter of Pipes	30	32	34	36	38	40	42	44	46	48
48	3.24	2.76	2.37	2.05	1.80	1.58	1.40	1.24	1.11	1.00
46	2.91	2.48	2.13	1.85	1.61	1.42	1.26	1.12	1.00	
44	2.61	2.22	1.91	1.65	1.44	1.27	1.12	1.00		
42	2.32	1.97	1.70	1.47	1.28	1.13	1.00			
40	2.05	1.75	1.50	1.30	1.14	1.00				
38	1.81	1.54	1.32	1.14	1.00					
36	1.58	1.34	1.15	1.00						
34	1.37	1.16	1.00							
32	1.18	1.00								
30	1.00									

The foregoing tables will be found useful in proportioning distribution lines.

Example: To find how many one-half inch pipes can be supplied by a 4-in. line, follow down the ½-in. vertical column to the number opposite 4-in. diameter of the first column, where the number 181.02 is found, which is the number of one-half inch lines that can be supplied by a 4-in. line.

Example: To find how many 12-in. lines can be supplied by a 48-in. line, follow horizontally along the 48-in. diameter of the first column, until you reach the 12-in. vertical column, where the number 32 is found, which is the result desired.

CALCULATION OF AREAS, VOLUMES, SURFACES REDUCED TO SIMPLE TERMS

Mensuration is arithmetic applied to geometry in determining the length of lines, the area of surfaces, and the volume of solids or bodies.

Definitions of geometrical terms, figures and principles. A point (.) has position only. A line (———) has length only. Area has length and breadth. A solid has length, breadth and thickness. Parallel means extended in the same direction, and equidistant at all points. Horizontal means parallel with water level; vertical or perpendicular, parallel with plumb line; diagonal, obliquely across a polygon. (Fig. 4.) Equilateral means, having equal sides. Quadrilateral, having four sides. An angle (Fig. 1) is formed by two straight lines diverging from a commont point called the vertex. A right angle (Fig. 2) is formed by two straight lines meeting perpendicularly. An oblique angle is either (acute—Fig. 1) smaller, or (obtuse—Fig. 3) greater than a right angle.

Fig. 1. Fig. 2. Fig. 3. Fig. 4. Rectangle. Parallel Lines.

A plane or plane figure has area or surface only—perfectly even.

A polygon is a plane figure having three or more equal sides.

A triangle is a plane figure bounded by three straight lines.

An equilateral triangle (Fig. 6) has all of its (3) sides equal. An isosceles triangle (Fig. 7) has two of its sides equal. A scalene triangle (Fig. 5) has none of its sides equal. The base is the side on which a geometrical figure is supposed to stand. The least distance between the base and the opposite angle dotted line (Fig. 7) or between parallel lines (Fig. 8) is called the perpendicular or altitude.

To find the area of a triangle. Rule—Multiply base by the altitude and take half of the product. Or, when the three sides are given. From half of the sum of the three sides, subtract each side separately; then multiply the half sum and the three remainders together and extract the square root. Find sq. ft. in a triangle, base 8 ft., altitude 9 ft.

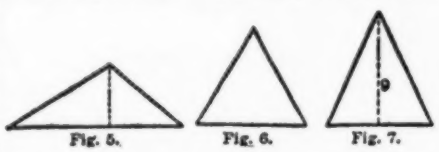


Fig. 5. Fig. 6. Fig. 7.

Answer—$(8 \times 9) \div 2 = 36$.

A parallelogram is a plane figure, bounded by four straight lines, whose opposite sides are equal, as a rectangle, a square, and a rhomboid.

A rectangle is a right angled parallelogram. A square is an equilateral rectangle. A rhomboid is an oblique angled parallelogram.

To find the area of a parallelogram. Rule—Multiply the length by the width.

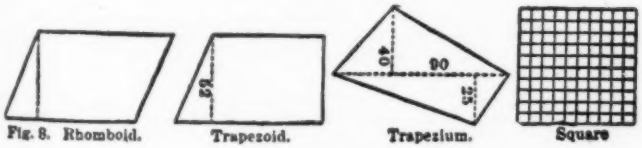


Fig. 8. Rhomboid. Trapezoid. Trapezium. Square

How many sq. ft. in a rectangle 17 by 24?

Answer—$17 \times 24 = 408$ sq. ft.

In a (square) floor 10 by 10?

Answer—$10 \times 10 = 100$ sq. ft.

Note—Dividing the area of a rectangle by one side gives the other side—if unknown.

A *trapezoid* is a quadrilateral having two of its sides parallel. To find its area. Rule—Multiply its average length by the width.

How many sq. yd. in a garden whose parallel sides are 60 and 80 yd., and width 52 yd.?

Answer—$(60 + 80 \div 2) = 70$; then, $70 \times 52 = 3{,}640$ sq. yd.

A *trapezoid* is a quadrilateral having two of its sides parallel.

To find its area. Rule—Form two triangles by a diagonal line, then multiply diagonal by sum of perpendiculars and take half of product.

Find sq. rods in field shaped like a trapezium, whose diagonal is 90 rods, and perpendiculars (25 and 40) 65 rd.

Answer—$90 \times 65 = 5850 \div 2 = 2925$ rd.

A *rightangled triangle* has one right angle. Its longest side is called hypotenuse, and the other two, base and perpendicular or altitude. To find its area. Rule—Multiply the base by the perpendicular and take half of the product.

How many square rods in a triangular field whose base is 70 rods and the perpendicular, 48 rods?

Answer — $(70 \times 48) \div 2 = 1680$ square rods.

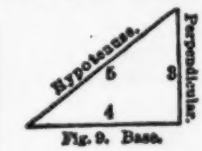


Fig. 9. Base.

Properties of the rightangled triangle. The square of the hypotenuse equals the sum of the squares of the base and the perpendicular. From this principle — illustrated by Fig. 10—we derive the following rules.

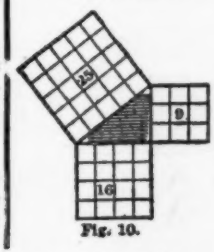


Fig. 10.

To find the hypotenuse. Rule—Add the square of the base and the square of the perpendicular, and of the sum extract square root.

A and B start from the same point, A going 4 miles due west and B, 3 miles due north; how far apart are they then?

$4^2 = 16$
$3^2 = 9$
$\sqrt{25} = 5$

Answer—5 miles.

The square of 4 (base)$=16$; of 3 (perpendicular)$=9$; the square root of their sum $(25)=5$, the hypotenuse.

To find the base or perpendicular. Rule—From the square of the hypotenuse, subtract the square of the other given side, and of their difference extract the square root.

Find the perpendicular of a triangular field whose hypotenuse is 75 rods, base 60 rods.
Answer—45 rods.

$75^2 = 5625$
$60^2 = 3600$
$\sqrt{2025} = 45$

Note—To find the difference between the squares of two numbers, simply multiply their sum by their difference.

To find the side of a square equal in area to any given quantity. Rule—Extract the square root of the given quantity.

Thus, the dimensions of a square field containing 4000 square rods must be $(\sqrt{4000} = 63.246)$ 63¼ rods, nearly. Proof: $63\frac{1}{4}^2 = 4000+$

To find the diagonal of a square. Rule—Multiply one side of the square by 10, diminish the product by 1% of itself and divide remainder by 7.

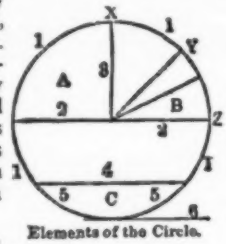
What is the diagonal of a field 35 rods square?
This is a simple way of finding the hypotenuse of a triangle whose base and perpendiculars are equal.

$35 \times 10 = 350$,
1% of $350 = 3.5$
$7)346.5$
Ans. (rd.) 49.5

The Circle

A circle is a plane figure bounded by a curved line, (1, 1, 1, 1) called circumference, every point of which is equally distant from

the center. The diameter is a straight line (2, 2) across a circle, through its center. The radius is a straight line (3) from the center to the circumference. An arc is any part of the circumference (5, 5). A chord, a straight line (4) joining ends of an arc. A tangent (6) touches circum. without cutting it. A segment is space (C) enclosed by arc and chord. A sector, space (B) enclosed by two radii and arc. A quadrant (A) is 90° or the fourth part of circle. A circle is divided into 360°; from X to Y is 45°; from X to Z, 90°. A sextant is one-sixth of a circle.



Elements of the Circle.

To find the *circumference* of a circle, the diameter being given. Rule—Multiply the diameter by 3 1/7; for greater accuracy, by 3.1416.

Find circumference of bicycle wheel; diam. 28 in.

Answer—28 × 3 1/7 = 88 in.

To find the *diameter* of a circle, the circumference being given. Rule—Divide the circumference by 3 1/7, or multiply it by .3183.

Circumference of a tree 144½ in., find diam.

Answer—144.5 × 3183 = 46 in.

To find the *area* of a circle. Rule—Multiply the square of the diameter by .7854; or the square of the radius by 3.1416; or the square of the circumference by .07958.

Find the area of a piston 20 in. in diam.

Answer—20^2 × .7854 = 314.16 sq. in.

Over how many sq. ft. can a cow graze, staked to a rope 50 ft. long? Here, 50 feet is the radius.

Answer—50^2 × 3.1416 = 7854 sq. ft.

To find the *radius* of a circle, the area being given. Rule—Multiply the area by .3183 and extract the square root of the product.

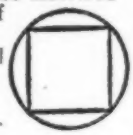
Find length of halter, tied to stake, that will enable horse to graze on 1 acre.

Answer—Square feet in acre, 43560 × .3183 = 13865; √13865 = 117¾ ft. long.

Note—The circumference of a circle is 3.1416 times greater than the diameter. The number 3.1416 (called Pi); its reciprocal, .3183; its 4th part .7854, its 6th part .5236, and others, should be committed to memory as they are indispensable factors in computing the areas and volumes of circular figures and bodies.

To find the *area of a sector* of a circle. Rule—Take such a part of the circle as the degrees in the given arc, are part of 360. Thus, a sector whose arc is 40°, contains 40/360 or 1/9 of the area of the circle.

To find the side of the greatest square that can be inscribed in a given circle. Rule—Multiply the diameter of the circle by .707; or the circumference by .225.



The diameter of a log is 24 inches; how large a sill can be cut from it?

24 × .707 = 17 in. square, nearly.

To inscribe the greatest equilateral triangle. Rule—Multiply the diameter of the circle by .886.

Side of greatest inscribed hexagon equals the radius of a circle.

To find the diameter of a circle that will inscribe a given square. Rule—Multiply the side of the desired square by 1.414.

What must be diam. of a log to cut a sill 12 in. sq.?

Answer—12 × 1.414 = 17 in.

The area of the greatest square inscribed in a given circle is exactly ½ of the area of the least square circumscribed about the same circle—or the square of its diameter.

To find the area between the two *concentric circles*. Rule—Take the difference between the area of each circle. A simpler way is to multiply the sum of the two diameters by their difference, and the product by .7854.

Find the area included between two concentric circles whose diameters are 30 and 50 inches. (80, sum; 20, dif.)

Answer—20 × 80 = 1600 × .7854 = 1256.64 sq. in.

To find the diameter of a circle whose area is equal to the area of a given square. Rule—Multiply one side of the given square by 1.1284.

To find the side of a square whose area is equal to the area of a given circle. Rule—Multiply the diameter of the given circle by .8862.

To find the diameter of three greatest equal circles that can be inscribed in a given circle. Rule—Multiply the diameter of the given circle by .464.

Find the diameters of the three greatest circles that can be inscribed in a circle 50 in. in diam.

Answer—50 × .464 = 23.2 in.

An *ellipse* is a plane figure bounded by an oval curved line and has a long and a short diameter or axis.

To find its circumference. Rule—Multiply the sum of the two diameters by 3.1416, and take half of the product.

Ellipse.

Find the circumference of an ellipse whose diameters are .41 and 29 ft.

(41 + 29) = 70 × 3.1416 ÷ 2 = 110 ft. nearly.

To find the *area of an ellipse*. Rule—Multiply the product of the two diameters by .7854.

How many square ft. are there in an elliptical platform whose diameters are 60 and 40 ft.?

60 × 40 = 2400 × .7854 = 1885 sq. ft. nearly.

Polygons

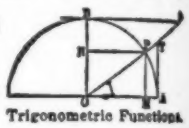
Triangle. Square. Pentagon. Hexagon. Octagon.

To find the area of polygons, having equal sides and equal angles. Rule—Multiply the square of one of the equal sides—of a triangle, by .433; of a pentagon, by 1.7205; of hexagon, by 2.5981; of octagon, by 4.8284.

One side of an equilateral triangle is 30 inches, and of an octagon, 10 in.

Find sq. in. in each.

30^2 × 433 = 389.7 in. T; 10^2 × 4.824 = 482.84 in. O.


Trigonometric Functions.

For the benefit of those who intend to study trigonometry and surveying, this illustration is inserted here. It will be an advantage and saving of time to be already familiar with the terms and the functions of the science when beginning its study.

P M, sine.
O M, cosine.
A T, tangent.
B S, cotangent.
O T, secant.
O S, cosecant.
M A, versed sine.
B N, conversed sine.

Cubes, Cones, Pyramids, Spheres,

A *cube* is a solid body, having six equal square sides. To find its area. Rule—Multiply area of one side by 6. To find its volume. Multiply the length, the breadth and the thickness together.

Cube.

Find sq. in. in surface of a 12 in. cube.

Answer—12^2 × 6 = 864.

How many cubic in. in a cubic foot?

Answer—*12^3 = 1728.

Find cu. ft. in a cu. mile.

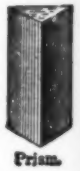
Answer—5280^3 = 147197952000.

A *parallelopiped* is a solid body whose six faces are all rectangles. To find its area. Rule—Add areas of its six sides. To find its volume. Same as the cube. How many cubic feet in a wagon bed 10½ feet long, 3 ft. wide and 1¼ ft. deep?

Parallelopiped.

Answer—10½ × 3 × 1¼ = 39⅜.

A *prism* is a solid having three or more rectangular sides, whose ends or bases are parallel plane figures. To find its area. Rule—Add areas of the sides and ends. To find its volume. Multiply the area of one end by the length.


Prism.

Find the area of a triangular prism, each of whose three sides are 10 by 25 inches.

Answers—836.6 sq. in.

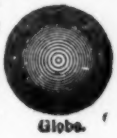
10^2 × .433 × 2 = 86.6 sq. in. in area of the two ends.

10 × 25 × 3 = 750 sq. in. area of sides. 86.0 + 750 = 836.6.

How many cubic inches in above prism, 10 by 25 inches?

Answer—10^2 × .433 = 43.3 × 25 = 1082½ cu. in.

A *globe* or *sphere* is a solid body, bounded by a uniformly curved surface. To find its area. Rule—Multiply the square of diameter by 3.1416; or the square of the circumference by .3183. To find its volume. Multiply the cube of diameter by .5236.


Globe.

How many square in. in the surface; and how many cubic in. in the volume of a globe 12 in. in diameter?

Answer—904.78 cu. in. $12^2 \times 3.1416 = 452.39$ sq. in. $12^3 \times .5236 = 904.78$ cu. in.

How many cubic miles in the earth, its diameter being nearly 8000 miles?

Answer—$2000^3 \times .5236 = 268083200000$ cubic mi.

Find greatest cube inscribed in a 26 in. globe.

Answer—$26 \times .577 = 15$ in.

To find the dimensions of a cube, equivalent in volume to a given globe. Rule—Multiply the diameter of given globe by 806.

To find the diameter of a globe, equivalent in volume to a given cube. Rule—Multiply one side of the cube by 1.2407.

A *cylinder* is a round body of uniform diameter whose ends are parallel plane figures. To find its area. Rule—Multiply the circumference by the length and to the product add the areas of both ends. To find its volume. Multiply the area of one end by length.

Cylinder.

Find the area of a cylinder 30 inches in circumference and 40 inches long.

Answer—1343.24 sq. in.

$30 \times 40 = 1200$ sq. in. in convex surface.

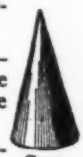
$30^2 \times .07958 \times 2 = 143.24$ sq. in. in the two ends.

Find cubic in. in a cylinder, diameter, 20 in., length 50 in.

Answer—$20^2 \times .7854 \times 50 = 15708$ cu. in.

A *cone* is a solid, which has a circular base and tapers uniformly to a point called vertex.

A *pyramid* is a solid, resembling a cone, having three or more triangular sides.


Cone.

Pyramid.

To find the area of a *cone or pyramid*. Rule—Multiply the circumference or perimeter of the base by the slant height, and to half of the product, add the area of the base.

Find the area or surface of a cone whose circumference at base is 40 in., and slant height 50 in.

Answer—1127.33 sq. in.

$50 \times 40 \div 2 = 1000$ sq. in. in convex surface.

$40^2 \times .07958 = 127.33$ in. base.

To find the volume of a cone or pyramid. Rule—Multiply the area of the base by the height and take ⅓ of the product.

How many cubic feet in a 6 sided pyramid, 10 ft. high, whose perimeter, at base is 15 ft. or each side 2½ ft.?

Answer—54.13 cu. ft.

$2\frac{1}{2}^2 \times 2.598 = 16.24$, area of base. $10 \times 16.24 \div 3 = 54.13$.

Find cu. in. in a cone whose height is 12½ in., and diameter of base 10 in.

Answer—$10^2 \times .7854 = 78.54$ area of base. $78.54 \times 12\frac{1}{2} \div 3 = 32.25$ cu. in.

The solid contents of the cone, globe, cylinder and the cube, all of equal dimensions, are in the ratio of 1, 2, 3 and 3.82 respectively. Thus, taking 1 foot as the height and the diameter; the cone contains .2618; the globe .5236, and the cylinder .7854 of a cubic foot. The cube equals 1 cu. ft.

The *frustum of a cone or pyramid* is the part which remains after cutting off the top, parallel to the plane of the base. To find the area of a frustum. Rule—Multiply the sum of circumferences, or perimeters, by the slant height, and to half of the product, add the area of each base.

Frustums.

Find the *area of a frustum* of a cone, whose slant height is 40 in., its greater circumference, 30 in., and its smaller one, 10 in.

Answer—879.58 sq. in.

$30 + 10 \times 40 \div 2 = 800$, sides. $30^2 + 10^2 \times .07958 = 79.58$, area of bases.

To find the *volume of any frustum*. Rule—Square both ends of one side, if angular, or the diameters of both ends or bases, if round. To the two squares add the product of the given ends or diameters; ⅓ of this sum will be the area of the average base of the frustum of a square pyramid, which multiplied by .7854 equals area of average base of frustum of a cone; multiplied by .433, of a three sided frustum, by 1.7205, of a five sided fr., by 2.5981, of a six sided frustum, by 4.8284, of an eight sided frustum. For volume: multiply average area by perpendicular height.

Find the volume or capacity of a round tank whose diameter is 15 ft. at base, 12 ft. at top, and 10 ft. deep. Ans.—14.37 cu. ft.

$12^2 = 144$
$15^2 = 225$
$12 \times 15 = 180$

$183 \times .7854 = 143.73$ sq. ft., area of av. base of Fr. of cone.

3)549(183, area of av. base of F. of sq. pyr.

$143.73 \times 10 = 1437.3$ cu. ft. $\times 7.48 = 10751$ gallons.

Find sq. ft. of lumber in a wagon tongue; large end, 4½ in. sq., small end, 2½ in., length, 9 ft. (108 in.).

Answer—$4\frac{1}{2} + 2\frac{1}{2}^2 + (4\frac{1}{2} \times 2\frac{1}{2}) \div 3 = 12\ 7/12$ sq. in., area of average base; $12\ 7/12 \times 108 = 1359$ cu. in. $\div 144 = 9\ 7/16$ sq. ft.

How many cu. ft. in a straight log, whose diameter at large end is 3 ft., small end, 2 ft., length 12 ft?

Answer—$3^2 + 2^2 + (3 \times 2) \div 3 \times .7854 = 4.974$ sq. ft., area of average base; $4.974 \times 12 = 59.69$ cu. ft.

A *spheroid* or elongated globe has a fixed and a revolving axis. To find its area. Rule—Multiply the revolving axis by the fixed axis, and that product by 3.1416. To find its volume. Rule—Multiply the square of the revolving axis by the fixed axis and that product by .5236. Find area, also the volume of spheroid; revolving axis, 20 in., fixed, 30 in.

Spheroid

$20 \times 30 \times 3.1416 = 1884.96$ sq. in. in area.

$20^2 \times 30 \times .5236 = 6283.2$ cu. in. in volume.

A *cylindrical ring* is formed by bending a cylinder. To find its area. Rule—Multiply sum of inside diam. and thickness of ring, by thickness, and the product by 9.87. To find its volume. Rule—Multiply sum of inside diam. and thickness by square of thickness, and product by 2.467.

Ring.

Find the area, also the volume of a ring whose inner diameter is 15 inches, and whose thickness is 5 inches.

$(15 + 5) \times 5 \times 9.87 = 987$ sq. in. in area. $(15 + 5) \times 5^2 \times 2.467 = 1233.5$ cu. in vol.

To find the dimensions of *greatest cube that can be inscribed in a given globe*. Rule—Multiply the diameter of the globe by .577.

The above material has been drawn from "Ropp's Calculator"—an extremely useful and inexpensive little booklet published by C. Ropp & Sons, of Chicago.

CONTENTS OF HORIZONTAL CYLINDERS

A Multiple Use Chart for Vertical as Well as Horizontal Tanks, Pipe Lines, Etc.

By J. TARRANT

Assoc. M. Inst. C. E., A. M. I. Mech. E.

Ruislip (Middlesex), England

THE alignment chart printed herewith gives a convenient method of finding the contents of cylindrical tanks placed with the axis horizontal for all depths of liquid in the tank.

It is usually the case that only a fair approximation of the tank contents is required, and the calculation by exact formula is not very readily done.

Formulas for horizontal cylindrical tanks contents are generally printed in two forms, one for use when the liquid level is above the centre and the other when the level is below the centre of the tank.

On the chart, the scale relating to the depth of liquid is continuous; that is to say, it applies whether the liquid level be in the upper or lower half of the section.

To use the chart, a straightedge is placed across the scales, and the intersections on the three scales give the related values. Line A gives the ratio of depth of liquid to the diameter of the tank; line B, the diameter of the tank in feet; and line C, the contents, in cubic feet and gallons, for each foot of length of the tank. In the example shown by the line across the chart, a tank 15 feet in diameter in which the contents are 10 feet 6 inches deep, will contain approximately 1,000 gallons per foot of length.

By using the fixed value of h/d = I, the chart also gives contents per foot of height of a cylinder with vertical axis, and also the contents of full pipes per foot of length.

Sometimes the dimensions of a tank or pipe line will not be in feet, but the chart may still be used. The contents will be in units which correspond to the dimensional units, and the scale of gallons will not apply. For example, if the diameter is taken in inches, the contents, *read on the cubic feet scale*, will be in *cubic inches* per *inch* of length.

The calculation of contents is clearly based on the area of the segment of a circle, which is what the contents scale on line C shows, and the calculation of segmental areas, in any dimensional units, may be made by use of the chart so long as the cubic feet scale is read, and units ascribed to this which correspond to the units used for the diameter. When the diameter is in feet, the area of the segment is in square feet; for meters, the area is in square meters; for inches, in square inches, and so on.

WEIGHTS AND MEASURES

Troy Weight

3.086 grains = 1 carat
24 grains = 1 dwt.
20 dwts. = 1 ounce
12 ounces = 1 pound

Used for weighing gold, silver, and jewels.

Apothecaries' Weight

20 grains = 1 scruple
3 scruples = 1 dram
8 drams = 1 ounce
12 ounces = 1 pound

The ounce and pound in this weight are the same as in Troy Weight.

Avoirdupois Weight

1 grain (Troy) = 1 grain (Apoth.) = 1 grain (Avdp.)
27 11/32 grams = 1 dram
16 drams = 1 ounce = 437.5 grains
16 ounces = 1 pound
25 pounds = 1 quarter
4 quarters = 1 cwt.
2,000 lbs. = 1 short ton
2,240 lbs. = 1 long ton
1 long ton = 1 British ton

Dry Measure

2 pints = 1 quart
1 quart = 67.2 cu. in.
1 British bushel = 1.032 U. S. bushel
8 quarts = 1 peck
4 pecks = 1 bushel

Liquid Measure

4 gills = 1 pint
16 fluid ounces = 1 pint
2 pints = 1 quart
4 quarts = 1 gallon
1 British Imperial gallon = 1.200 U. S. gallons
1 cubic foot of water contains 7.48 gallons and weighs 62.321 lb.
1 gallon = 231 cu. in.
31½ gallons = 1 barrel
2 barrels = 1 hogshead

Linear Measure

1 mil = 0.001 inch
12 inches = 1 foot
3 feet = 1 yard
5½ yards = 1 rod
40 rods = 1 furlong
8 furlongs = 1 statute mile
5280 feet = 1 statute mile
3 miles = 1 league

Square Measure

1 circular mil = 0.7854 square mils
1,000,000 square mils = 1 square inch
144 square inches = 1 sq. ft.
9 sq. ft. = 1 sq. yard
4 roods = 1 acre = 43560 sq. ft.
30¼ sq. yds. = 1 sq. rod
40 sq. rods = 1 rood
640 acres = 1 sq. mile

Surveyor's Measure

7.92 inches = 1 link
25 links = 1 rod
4 rods = 1 chain
10 sq. chains or 160 sq. rods = 1 acre
36 sq. miles (6 miles square) = 1 township
43560 sq. ft. = 1 acre
640 acres = 1 sq. mile

Mariners' Measure

6.08 feet = 1 fathom
120 fathoms = 1 cable length
8.31 cable lengths = 1 nautical mile
6080 feet = 1 nautical mile
1 nautical mile = 1.15 statute mile
1 knot is a speed of 1 nautical mile per hour

Paper Measure

24 sheets = 1 quire
20 quires = 1 ream
2 reams = 1 bundle
5 bundles = 1 bale

Cubic Measure

1 cu. cm. = .061 cu. in.
27 cu. ft. = 1 cu. yd.
40 cu. ft. = 1 ton (shipping)
231 cu. in. = 1 standard gallon
2150.42 cu. in. = 1 standard bushel
1 cu. ft. = 4/5 of a bushel
1728 cu. in. = 1 cu. ft.
128 cu. ft. = 1 cord (wood)

Household Measure

60 drops = 1 teaspoon
2 teaspoons = 1 dessert spoon
3 teaspoons = 1 tablespoon
16 tablespoons = 1 cup
2 gills = 1 cup.
2 cups = 1 pint

METRIC EQUIVALENTS

Linear Measure

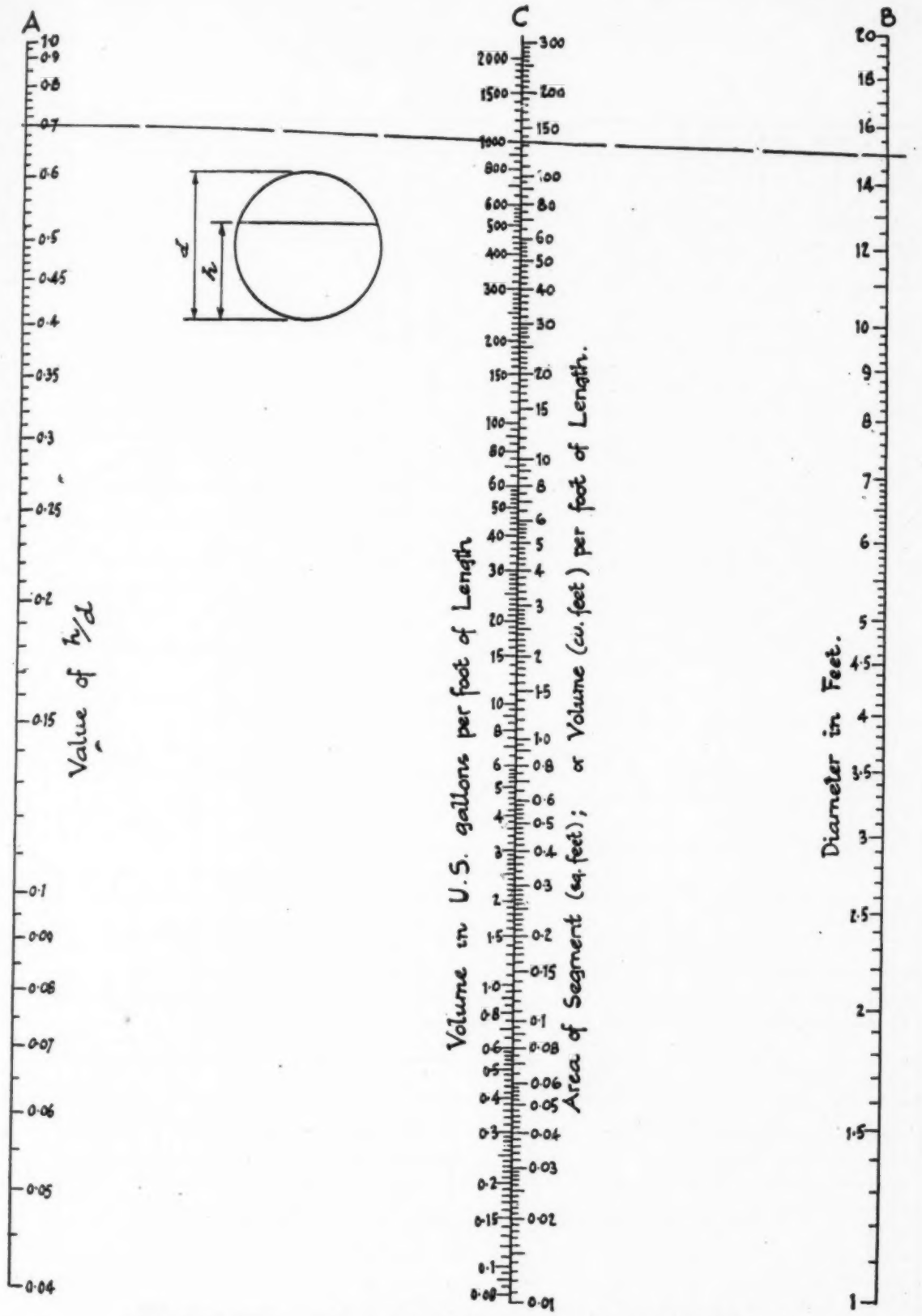
1 millimeter = 0.03937 inches
1 centimeter = 0.3937 inches
1 decimeter = 3.937 in. = 0.328 ft.
1 meter = 39.37 in. = 1.0936 yards
1 dekameter = 1.9884 rods
1 kilometer = 0.62137 mile
1 inch = 2.54 centimeters
1 foot = 3.048 decimeters
1 rod = 0.5029 dekameter
1 yard = 0.9144 meter
1 mile = 1.6093 kilometers

Square Measure

1 sq. cm. = 0.1550 sq. in.
1 sq. decimeter = 0.1076 sq. ft.
1 sq. meter = 1.196 sq. yds.
1 hectare = 2.47 acres
1 sq. kilometer = 0.386 sq. miles
1 sq. in. = 6.452 sq. cm.
1 sq. foot = 9.2903 sq. decimeters
1 sq. yard = 0.8361 sq. meter
1 sq. mile = 2.59 sq. kilometers

Weights

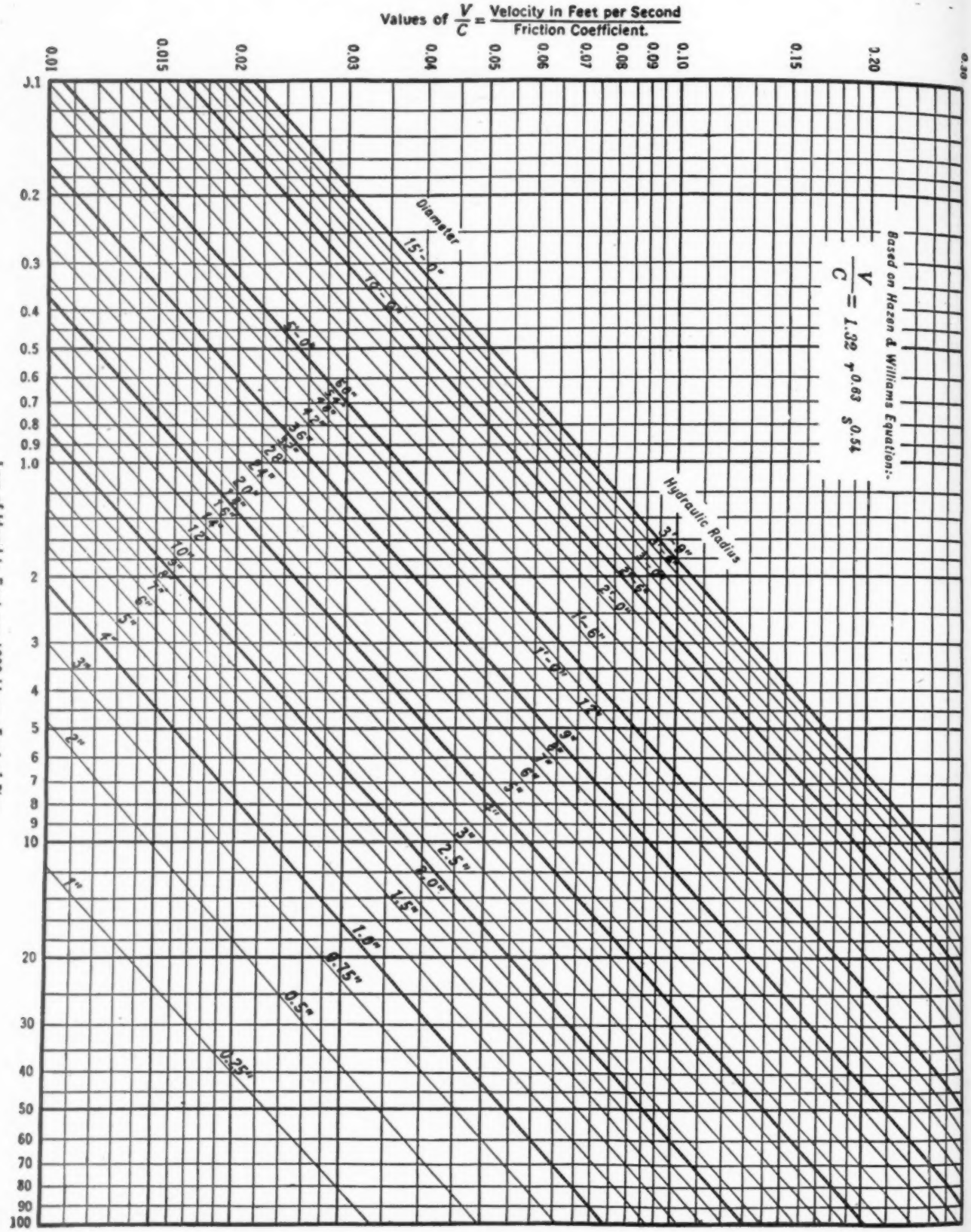
1 dyne = .00102 grains
1 gram = 0.03527 ounces
1 kilogram = 2.2046 lbs.
1 metric ton = 2205 lbs.
1 pound = 0.4536 kilograms
1 metric ton = 1.1023 short tons
1 ounce = 28.35 grams = 437.5 grains



CONTENTS OF HORIZONTAL CYLINDERS.

Copyright 1942: J. Tarrant, Assoc. M. Inst. C.E., A.M.I. Mech. E.

CHART OF LOSS OF HEAD IN FEET PER 1000 FT. OF PIPE



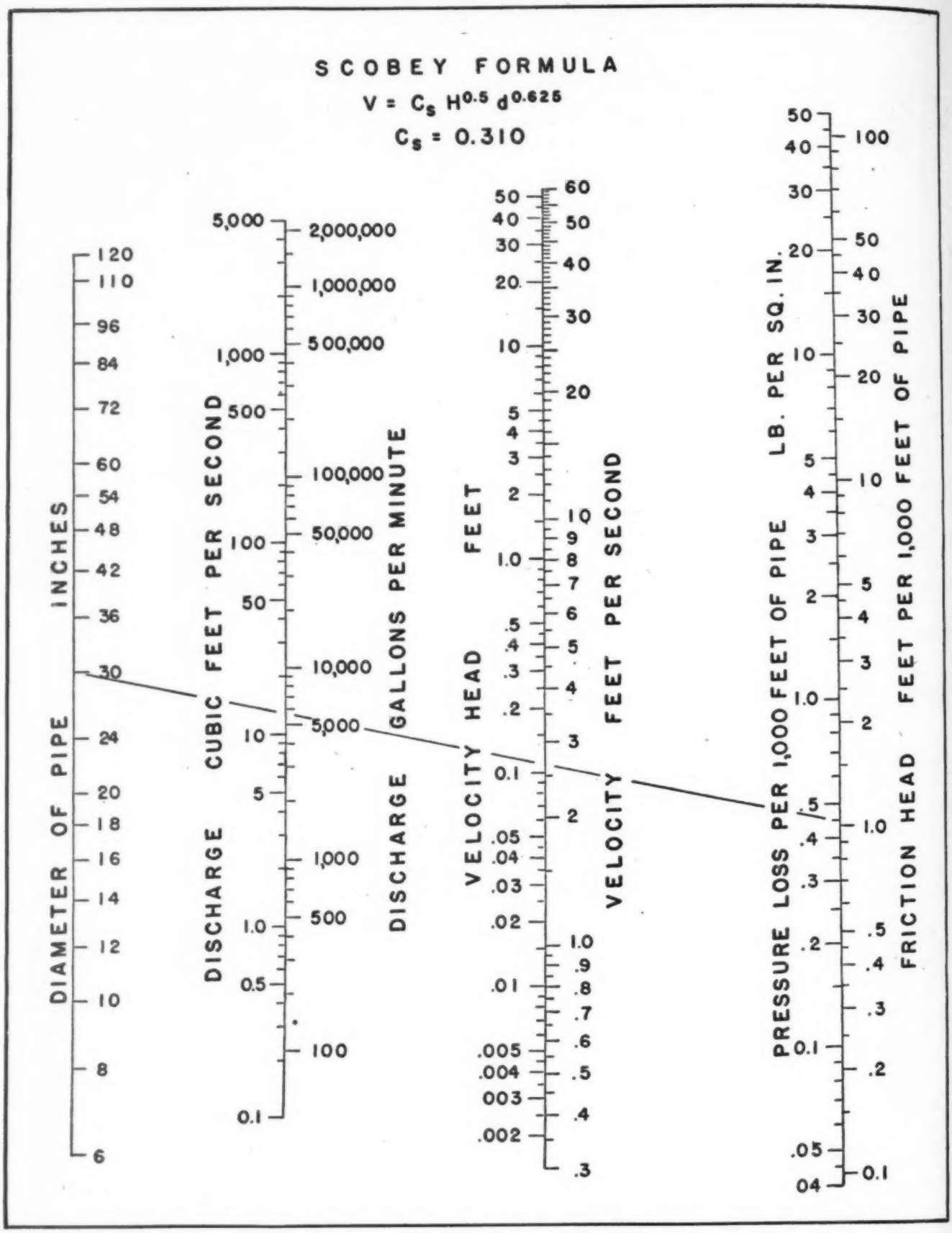
From "Hydro-Electric Handbook"—John Wiley & Sons

VELOCITY IN PIPES

Rate of Flow in Gals. per Min.	NOMINAL DIAMETER OF PIPE (Velocity in Feet Per Second)													Rate of Flow in Gals. per Min.
	⅛"	¼"	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	5"	6"	
1	5.60	3.08	1.67	1.05											1
2		6.16	3.35	2.10	1.20										2
3			5.02	3.16	1.80	1.12									3
4			6.70	4.21	2.41	1.49	0.86	0.63							4
5			8.37	5.26	3.01	1.86	1.07	0.79							5
10				10.52	6.02	3.72	2.14	1.57	1.02	0.65	0.45				10
15					9.02	5.60	3.21	2.36	1.53	0.98	0.68				15
20					12.03	7.44	4.29	3.15	2.04	1.31	0.91				20
25						9.30	5.36	3.94	2.55	1.63	1.13				25
30						11.15	6.43	4.72	3.06	1.96	1.36				30
35						13.02	7.51	5.51	3.57	2.29	1.58				35
40						14.88	8.58	6.30	4.08	2.61	1.82	1.02			40
45							9.65	7.08	4.60	2.94	2.04	1.15			45
50							10.72	7.87	5.11	3.27	2.27	1.28			50
70							15.01	11.02	7.15	4.58	3.18	1.79	1.14		70
75								11.80	7.66	4.90	3.40	1.92	1.22		75
100								15.74	10.21	6.54	4.54	2.55	1.63	1.10	100
120								18.89	12.25	7.84	5.45	3.06	1.96	1.36	120
125									12.75	8.16	5.66	3.19	2.04	1.42	125
150									15.32	9.80	6.80	3.84	2.45	1.70	150
175									17.85	11.40	7.94	4.46	2.86	1.98	175
200	8"								20.42	13.07	9.08	5.11	3.27	2.27	200
225										14.70	10.20	5.75	3.67	2.55	225
250	1.60									16.30	11.32	6.38	4.08	2.84	250
270	1.73										12.25	6.90	4.41	3.06	270
275	1.76										12.50	7.03	4.49	3.12	275
300	1.92										13.62	7.66	4.90	3.40	300
350	2.24	10"										8.94	5.72	3.98	350
400	2.56											10.21	6.54	4.54	400
450	2.88	1.84										11.49	7.35	5.11	450
470	3.01	1.92	12"									12.00	7.68	5.34	470
475	3.04	1.94										12.10	7.75	5.40	475
500	3.20	2.04	1.42									12.77	8.17	5.68	500
550	3.52	2.25	1.56										8.99	6.24	550
600	3.84	2.45	1.70	14"									9.80	6.81	600
650	4.16	2.65	1.85	1.30									10.62	7.38	650
700	4.48	2.86	1.99	1.40									11.44	7.94	700
750	4.80	3.06	2.13	1.50									12.26	8.50	750
800	5.12	3.27	2.27	1.60										9.08	800
850	5.45	3.47	2.41	1.70	15"									9.65	850
900	5.76	3.67	2.56	1.80	1.67									10.20	900
950	6.08	3.88	2.70	1.90	1.76									10.77	950
1000	6.40	4.08	2.84	2.00	1.85									11.34	1000
1050	6.72	4.29	2.98	2.10	1.93									11.90	1050
1100	7.04	4.49	3.13	2.20										12.48	1100
1150	7.36	4.70	3.27	2.30	2.02	16"								13.05	1150
1200	7.68	4.90	3.41	2.40	2.11									13.61	1200
1250	8.00	5.41	3.55	2.50	2.20	1.99								14.20	1250
1500	9.60	6.12	4.26	3.05	2.64	2.09									1500
2000	12.80	8.10	5.68	4.00	3.52	3.09									2000
2500		10.20	7.10	5.01	4.40	3.98	20"	24"							2500
3000		12.24	8.52	6.01	5.28	4.78	3.07		30"						3000
3500		14.50	9.95	7.02	6.16	5.58	3.53	2.43							3500
4000			11.36	8.02	7.04	6.33	4.10	2.83	1.81						4000
4200			11.92	8.42	7.40	6.70	4.30	2.97	1.90						4200
4500			12.78	9.02	7.92	7.17	4.61	3.19	2.04						4500
5000			14.20	10.02	8.80	7.96	5.12	3.54	2.26	36"					5000
5500				11.01	9.69	8.77	5.63	3.90	2.49						5500
6000				12.00	10.56	9.56	6.14	4.25	2.72	1.57					6000
6500				13.00	11.44	10.36	6.66	4.60	2.94	2.05					6500
7000				14.02	12.32	11.16	7.16	4.97	3.17	2.21					7000
7200					13.20	11.50	7.38	5.16	3.26	2.27					7200
7500					14.00	11.96	7.68	5.32	3.40	2.37					7500
8000							8.20	5.66	3.62	2.52					8000
8500							8.70	6.02	3.85	2.68					8500
9000							9.21	6.38	4.08	2.84	42"				9000
9500							9.72	6.72	4.31	3.00					9500
10000							10.24	7.08	4.58	3.15	2.31				10000
10500								7.44	4.76	3.30	2.43				10500
11000								7.79	4.99	3.46	2.55				11000
11500								8.15	5.22	3.62	2.66				11500
12000								8.50	5.44	3.78	2.78				12000
12500								8.85	5.67	3.93	2.89				12500
13000								9.20	5.90	4.00	3.01				13000
13500								9.56	6.12	4.25	3.13				13500

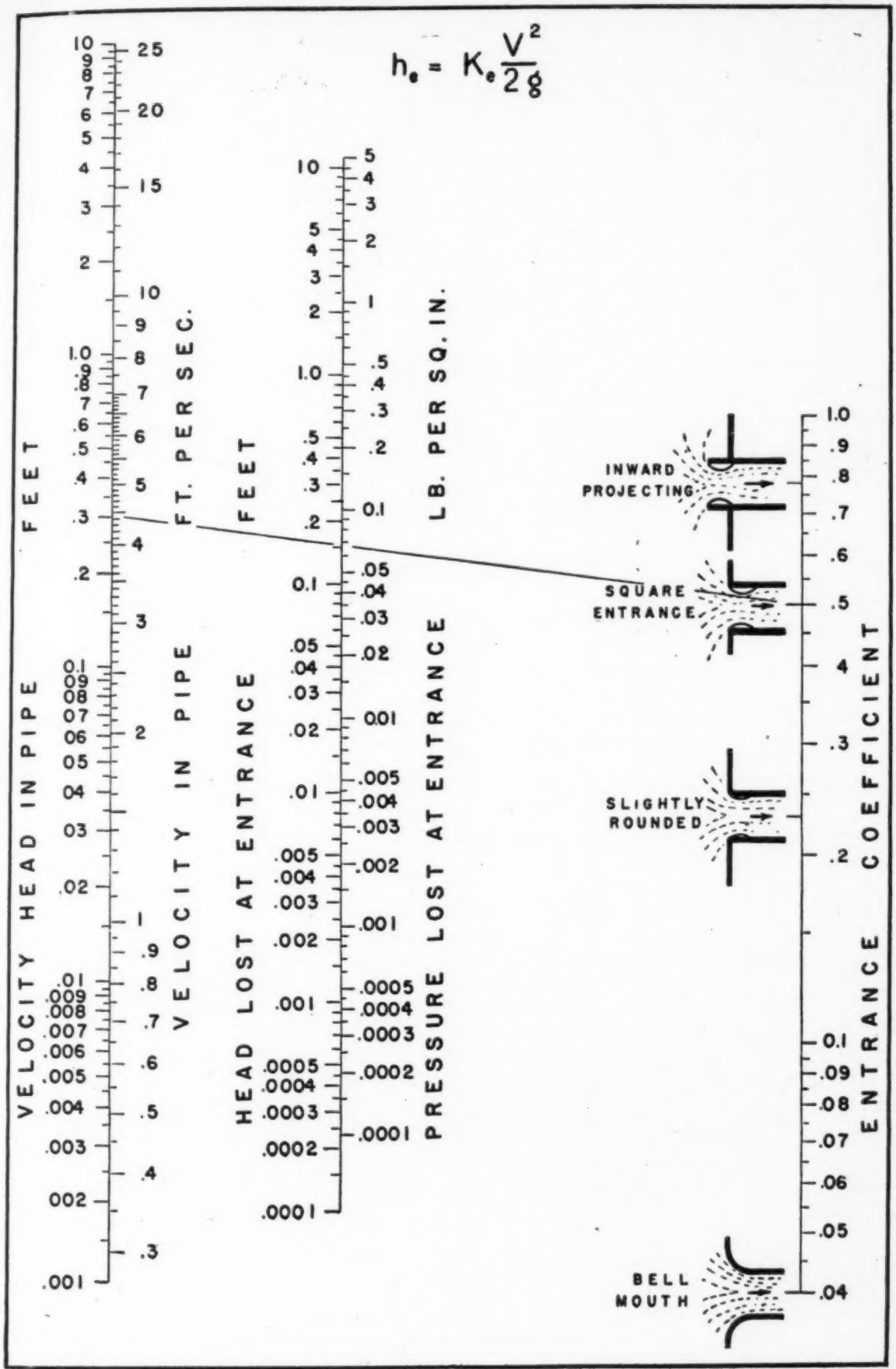
This table is taken from "Hydraulic Data," published by Gould's Pumps, Inc.

FLOW OF WATER IN CONCRETE PIPE

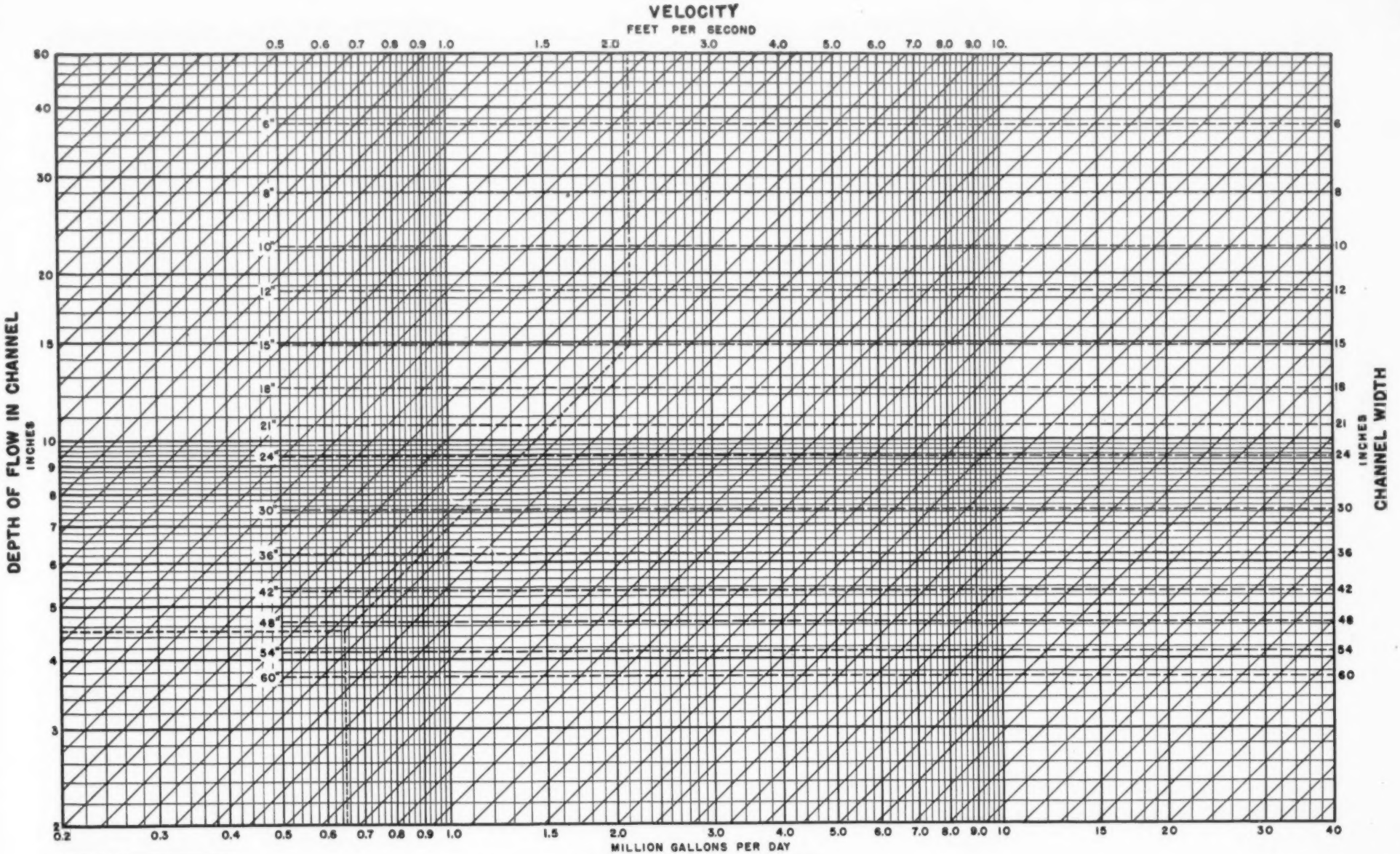


Courtesy of J. R. Griffith, U. S. Navy, and Western Construction News.

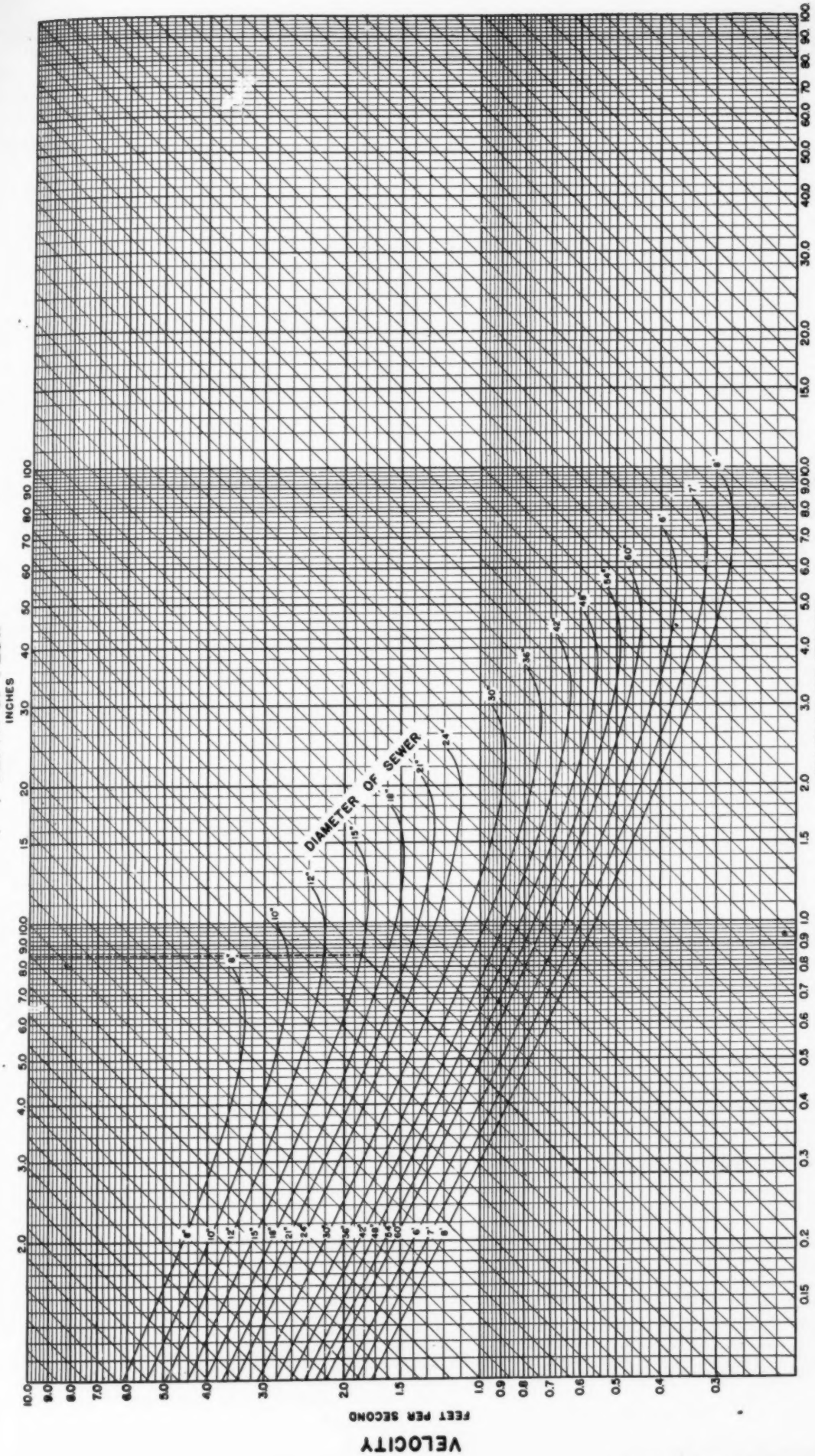
HYDRAULIC ENTRANCE LOSSES



Courtesy of J. R. Griffith, U. S. Navy, and Western Construction News.


VELOCITY
FEET PER SECOND
0.5 0.6 0.7 0.8 0.9 1.0 1.5 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.
DEPTH OF FLOW IN CHANNEL
INCHES
CHANNEL WIDTH
INCHES
6" 8" 10" 12" 15" 18" 21" 24" 30" 36" 42" 48" 54" 60"
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.5 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10 15 20 30 40
MILLION GALLONS PER DAY
EXAMPLE:
FLOW - 0.65 M.G.D.
DEPTH FLOW - 4½ INCHES.
CHANNEL - 15 INCHES.
VELOCITY = 2.15 F.P.S.
RATE OF FLOW IN CHANNEL
RECTANGULAR CHANNEL

This very useful graph for use in design or in determining rates of flow or velocities in existing rectangular channels is reproduced through courtesy of Chicago Pump Co.



This very useful graph for use in design or in determining velocities or rates of flow in existing pipe lines and sewers is reproduced through courtesy of Chicago Pump Co.

RELATIVE SIZES OF BRANCHES AND WATER MAINS

Size of Main	Number and Size of Branches Main Will Supply—Running Full
½"	Two—⅜"
¾"	Two—½"
1"	Two—¾"
1¼"	Two—1" *or* One—1" and Two—¾"
1½"	Two—1¼" *or* One—1¼" and Two—¾"
2"	Two—1½" *or* One—1½" and Two—1¼"
2½"	Two—1½" and Two—1¼" *or* One—2" and Two—1¼"
3"	One—2½" and One—2" *or* Two—2" and Two—1½"
3½"	Two—2½" *or* One—3" and One—2" *or* Four—2"
4"	One—3½" and One—2½" *or* Two—3" *or* Three—2½" and One—2" *or* Six—2"

POWER AND HEAT EQUIVALENTS

1 horsepower-hour = 0.746 kilowatt-hour = 1,980,000 foot-pounds = 2550 B. T. U. (British thermal units) = 2.64 pounds of water evaporated at 212° F. = 17 pounds of water raised from 62° to 212° F.

1 kilowatt-hour = 1000 watt-hours = 1.34 horsepower-hour = 2,653,200 foot-pounds = 3,600,000 joules = 3420 B. T. U. = 3.54 pounds of water evaporated at 212° F. = 22.8 pounds of water raised from 62° to 212° F.

1 horsepower = 746 watts = 0.746 kilowatt = 33,000 foot-pounds per minute = 550 foot-pounds per second = 2550 B. T. U. per hour = 42.5 B. T. U. per minute = 0.71 B. T. U. per second = 2.64 pounds of water evaporated per hour at 212° F.

1 kilowatt = 1000 watts = 1.34 horsepower = 2,653,200 foot-pounds per hour = 44,220 foot-pounds per minute = 737 foot-pounds per second = 3420 B. T. U. per hour = 57 B. T. U. per minute = 0.95 B. T. U. per second = 3.54 pounds of water evaporated per hour at 212° F.

1 watt = 1 joule per second = 0.00134 horsepower = 0.001 kilowatt = 3.42 B. T. U. per hour = 44.22 foot-pounds per minute = 0.74 foot-pounds per second = 0.0035 pounds of water evaporated per hour at 212° F.

1 B. T. U. (British thermal unit) = 1052 watt-seconds = 778 foot-pounds = 0.252 calorie = 0.000292 kilowatt-hour = 0.000391 horsepower-hour = 0.00104 pounds of water evaporated at 212° F.

1 foot-pound = 1.36 joule = 0.000000377 kilowatt-hour = 0.00129 B. T. U. = 0.0000005 horsepower-hour.

1 joule = 1 watt-second = .000000278 kilowatt-hour = 0.00095 B. T. U. = 0.74 foot-pound.

EQUIVALENTS OF OUNCES IN WATER AND MERCURY

Ounces	Inches of Water	Inches of Mercury	Ounces	Inches of Water	Inches of Mercury
.3	.521	.038	8	13.9	1.020
.576	1.0	.073	9	15.6	1.148
1	1.7	.128	10	17.4	1.275
2	3.5	.255	11	19.1	1.403
3	5.2	.383	12	20.8	1.530
4	6.9	.510	13	22.6	1.658
5	8.7	.638	14	24.3	1.785
6	10.4	.765	15	26.3	1.913
7	12.2	.893	16	27.8	2.036

WHAT LEAKS COST

SIZE OF OPENING	AIR		STEAM		WATER	
	Number of Cu. Ft. Wasted per Month 100 Lbs. Pressure	Total Cost of Waste per Month @ 10c per M Cu. Ft.	Number of Lbs. Wasted per Month 100 Lbs. Pressure	Total Cost of Waste per Month @ 10c per M Lbs.	Number of Gallons Wasted per Month 40 Lbs. Pressure	Total Cost of Waste per Month @ 10½c per M Gals.
1" / 2	17,798,400	$1,779.84	805,000	$483.00	1,231,000	$192.00
3" / 8	9,979,200	997.92	460,000	276.00	692,400	108.00
1" / 4	4,449,600	444.96	203,000	121.80	307,700	48.00
1" / 8	1,114,560	111.46	50,500	30.30	76,980	12.00
1" / 16	278,640	27.86	12,750	7.65	19,280	3.00
1" / 32	69,552	6.96	3,175	1.91	4,800	0.80

Courtesy M. B. Skinner Co

BLOTTING OUT WASTE

Safe Water
delivered night and day
Costs Less
than anything else you buy
· · *but* · ·
Don't Ignore Leaks!

Satisfied customers are worth more to us than revenue secured from water uselessly passing through meters.

INDIANAPOLIS WATER CO.

What Leaks May Cost

Size of Leak	Gallons per 24 Hours	Gallons per Month	Cost per Month
½"	47,600	1,451,800	$156.21
¼"	12,300	375,150	60.05
⅛"	3,200	97,600	19.65
1/16"	860	26,230	6.35
1/32"	215	6,550	1.97

(Above estimates are based on Indianapolis pressure without allowance for friction loss)

The above is a reproduction of the top side of a little blotter sent out to customers, reminding them of the high cost of allowing fixture leaks to persist. If as good at blotting waste as ink, the scheme is praiseworthy.

Incidentally, the Indianapolis Water Company gets in a good public-relations message about satisfied customers being worth more to them than the added revenue from the uselessly metered wastage.

NUMBER OF TAPS THAT CAN BE TAKEN FROM PIPE OF VARIOUS SIZES

Diameter of Pipe	SIZE OF TAPS IN INCHES																							
in Inches	¾	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	12	14	15	16	18	20	22	24
2	11	5	3	2	1																			
2½	20	9	5	3	1	1																		
3	32	15	8	5	2	1	1																	
3½	47	22	13	8	4	2	1	1																
4	65	32	18	11	5	3	2	1	1															
4½	88	42	24	15	7	4	2	1	1	1														
5	114	55	32	20	9	5	3	2	1	1	1													
6	181	88	50	32	15	8	5	3	2	2	1	1												
7	266	129	74	47	22	13	8	5	4	3	2	1	1											
8	371	181	103	65	32	18	11	7	5	4	3	2	1	1										
9		243	139	88	42	24	15	10	7	5	4	2	1	1	1									
10		316	181	114	55	32	20	13	9	7	5	3	2	1	1	1								
12			285	181	88	50	32	21	15	11	8	5	3	2	2	1	1							
14			419	266	129	74	47	32	22	17	13	8	5	4	3	2	1	1						
15				316	154	88	55	38	27	20	15	9	6	4	3	2	1	1	1					
16				371	181	103	65	44	32	23	18	11	7	5	4	3	2	1	1	1				
18					243	139	88	59	42	32	24	15	10	7	5	4	2	1	1	1	1			
20					316	181	114	78	55	41	32	20	13	9	7	5	3	2	2	1	1	1		
22						229	145	99	70	52	40	25	17	12	9	7	4	3	2	2	1	1	1	
24						285	181	123	88	65	50	32	21	15	11	8	5	3	3	2	2	1	1	1

EXPANSION CHART*

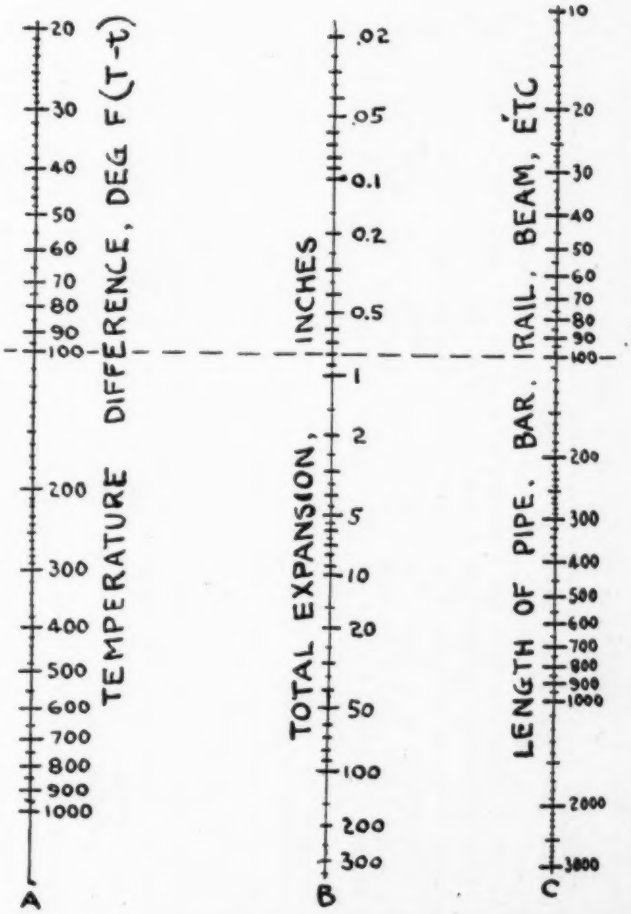
This chart is useful for determining the expansion in piping, rods, tubes, beams, shafts, columns, struts, etc., for any ordinary temperature difference. It makes "longhand figuring" unnecessary. Simply lay a straight-edge across the chart once or stretch a fine black thread across, as indicated by the dotted line, and the problem is solved.

Example: If a certain pipe line 100 ft. long is subjected to a temperature variation of 100 deg. F., what will be the total expansion in inches?

Simply connect the 100 deg. *temperature difference*, column A, with the 100 ft. length, column C. The intersection with column B gives the answer as 0.8 in. That is all there is to it.

The chart can also be used for determining the allowable temperature difference where a definite amount of space is available for expansion and contraction. Thus if the length of the pipe is 100 ft. and the allowable expansion is 0.8 in. the same line would show that a temperature difference of 100 deg. F. would be the limiting amount.

*From an article by W. F. Schaphorst, M.E., Newark, N. J., in WATER WORKS & SEWERAGE, March, 1939.



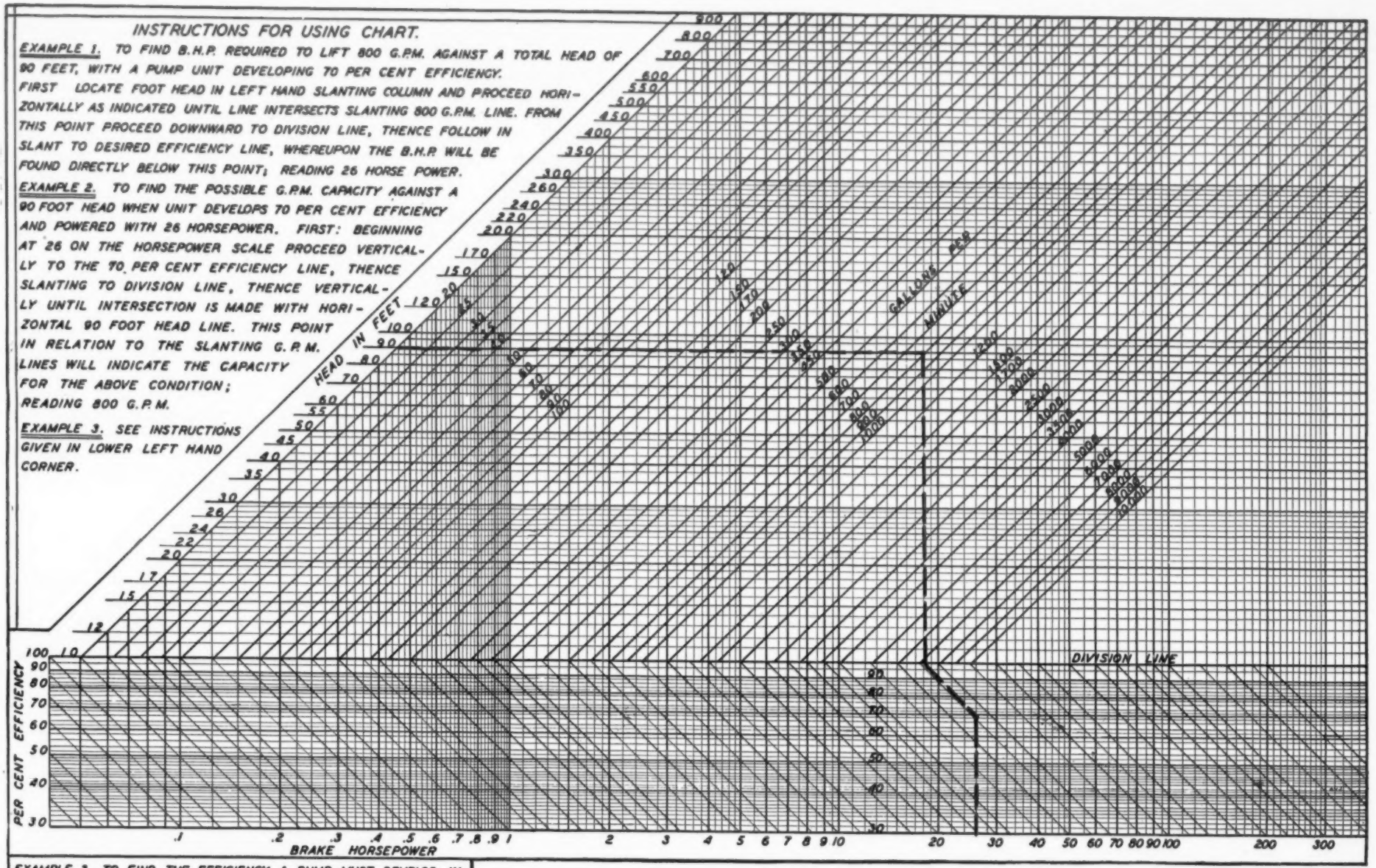
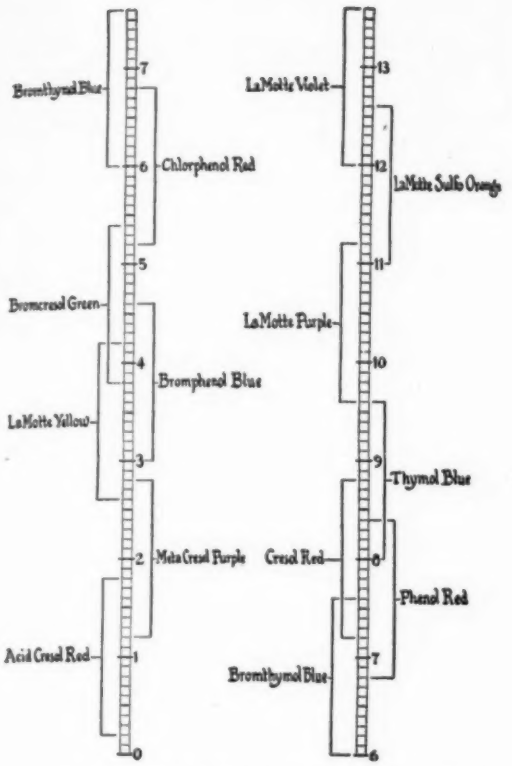

INSTRUCTIONS FOR USING CHART.
EXAMPLE 1. TO FIND B.H.P. REQUIRED TO LIFT 800 G.P.M. AGAINST A TOTAL HEAD OF 90 FEET, WITH A PUMP UNIT DEVELOPING 70 PER CENT EFFICIENCY. FIRST LOCATE FOOT HEAD IN LEFT HAND SLANTING COLUMN AND PROCEED HORIZONTALLY AS INDICATED UNTIL LINE INTERSECTS SLANTING 800 G.P.M. LINE. FROM THIS POINT PROCEED DOWNWARD TO DIVISION LINE, THENCE FOLLOW IN SLANT TO DESIRED EFFICIENCY LINE, WHEREUPON THE B.H.P. WILL BE FOUND DIRECTLY BELOW THIS POINT; READING 26 HORSE POWER.
EXAMPLE 2. TO FIND THE POSSIBLE G.P.M. CAPACITY AGAINST A 90 FOOT HEAD WHEN UNIT DEVELOPS 70 PER CENT EFFICIENCY AND POWERED WITH 26 HORSEPOWER. FIRST: BEGINNING AT 26 ON THE HORSEPOWER SCALE PROCEED VERTICALLY TO THE 70 PER CENT EFFICIENCY LINE, THENCE SLANTING TO DIVISION LINE, THENCE VERTICALLY UNTIL INTERSECTION IS MADE WITH HORIZONTAL 90 FOOT HEAD LINE. THIS POINT IN RELATION TO THE SLANTING G.P.M. LINES WILL INDICATE THE CAPACITY FOR THE ABOVE CONDITION; READING 800 G.P.M.
EXAMPLE 3. SEE INSTRUCTIONS GIVEN IN LOWER LEFT HAND CORNER.
HEAD IN FEET
GALLONS PER MINUTE
DIVISION LINE
PER CENT EFFICIENCY
BRAKE HORSEPOWER
EXAMPLE 3. TO FIND THE EFFICIENCY A PUMP MUST DEVELOP IN ORDER TO DELIVER 800 G.P.M. AGAINST A 90 FOOT HEAD WITH 26 HORSEPOWER. PROCEED AS IN EXAMPLE 1 TO DIVISION LINE, THEN SLANTWISE UNTIL INTERSECTION IS MADE WITH THE VERTICAL 26 HORSEPOWER LINE. THIS POINT WILL LOCATE THE HORIZONTAL EFFICIENCY LINE; READING 70 PER CENT.

Chart for Determining Head, Capacity, Efficiency, Horse Power With Any Three Conditions Known

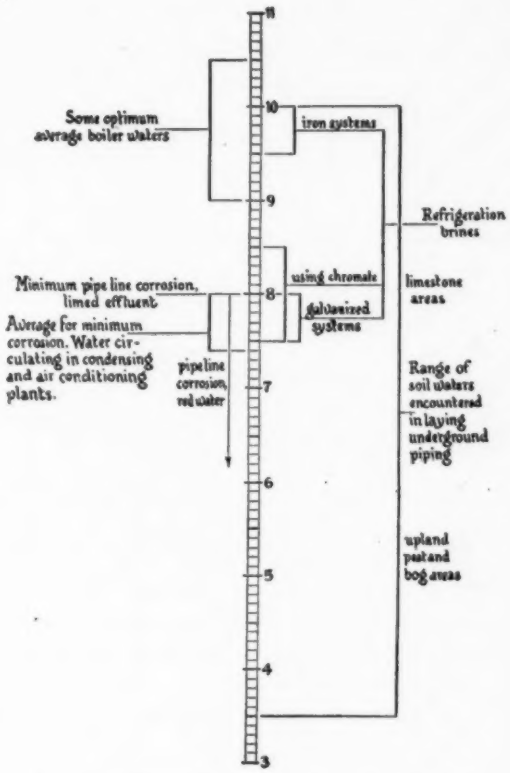
(From the Peerless Pump Bulletin)

(From the Peerless Pump Bulletin)

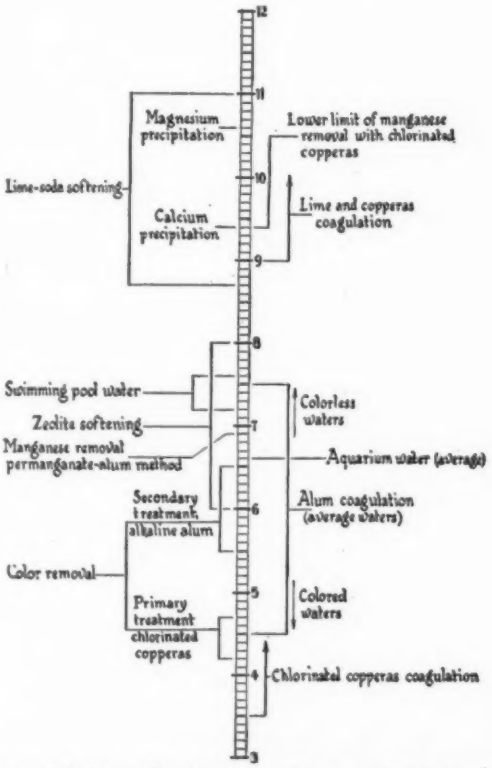
pH ZONES OF IMPORT IN WATER SUPPLY AND SEWAGE TREATMENT PRACTICE *



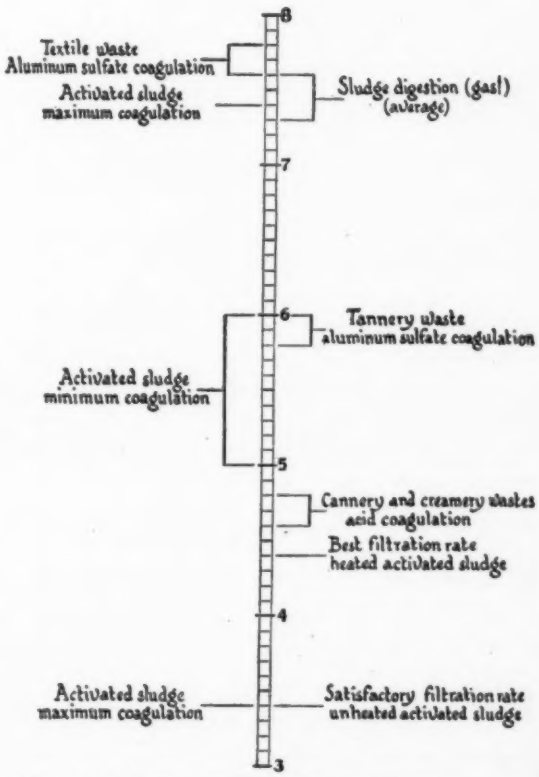
Ranges of Selected Indicators for pH Determination



Approximate pH Zones Encountered in Common Corrosion Problems



Approximate pH Zones for Water Purification

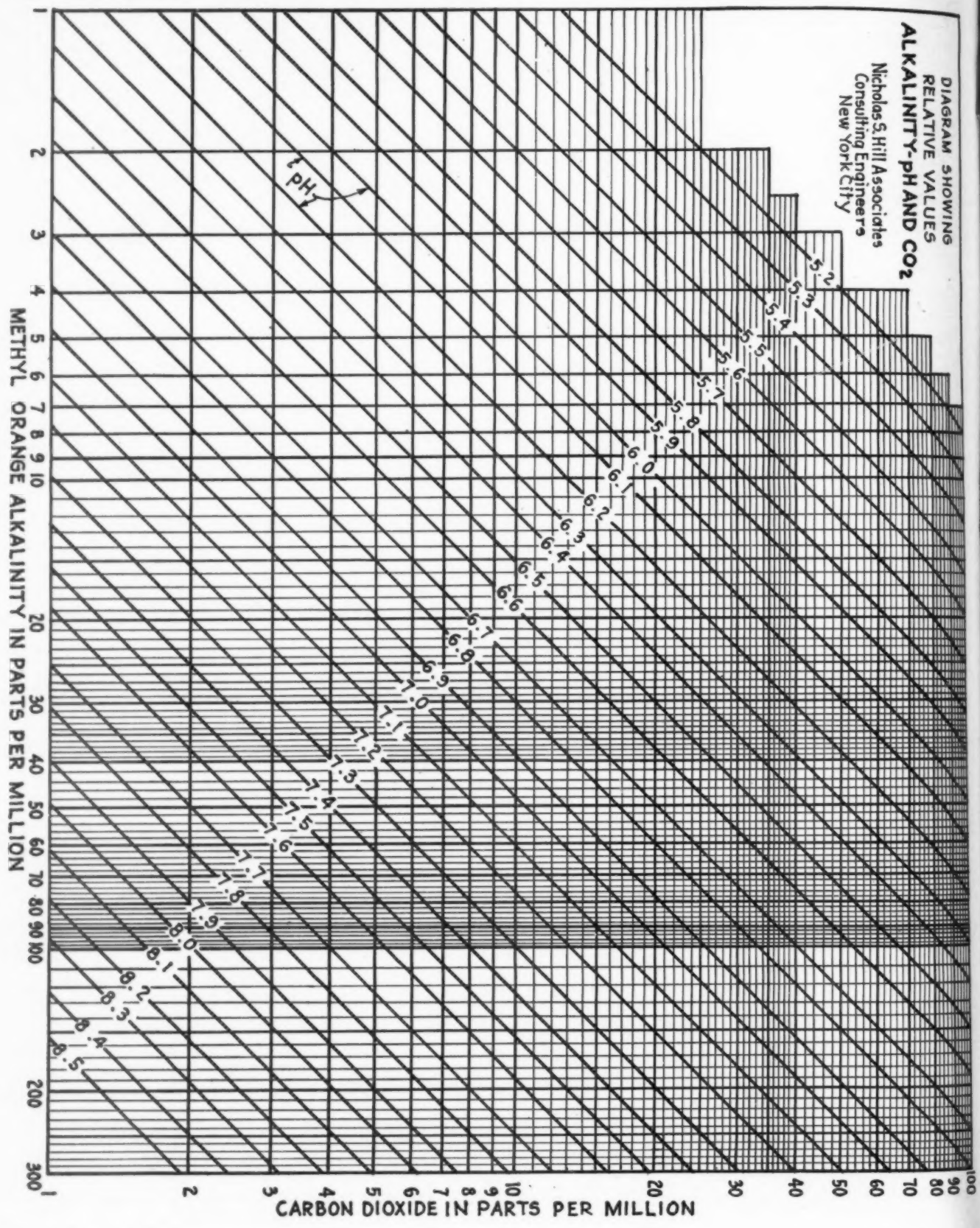


Approximate pH Zones for Treatment of Sewages and Some Industrial Wastes

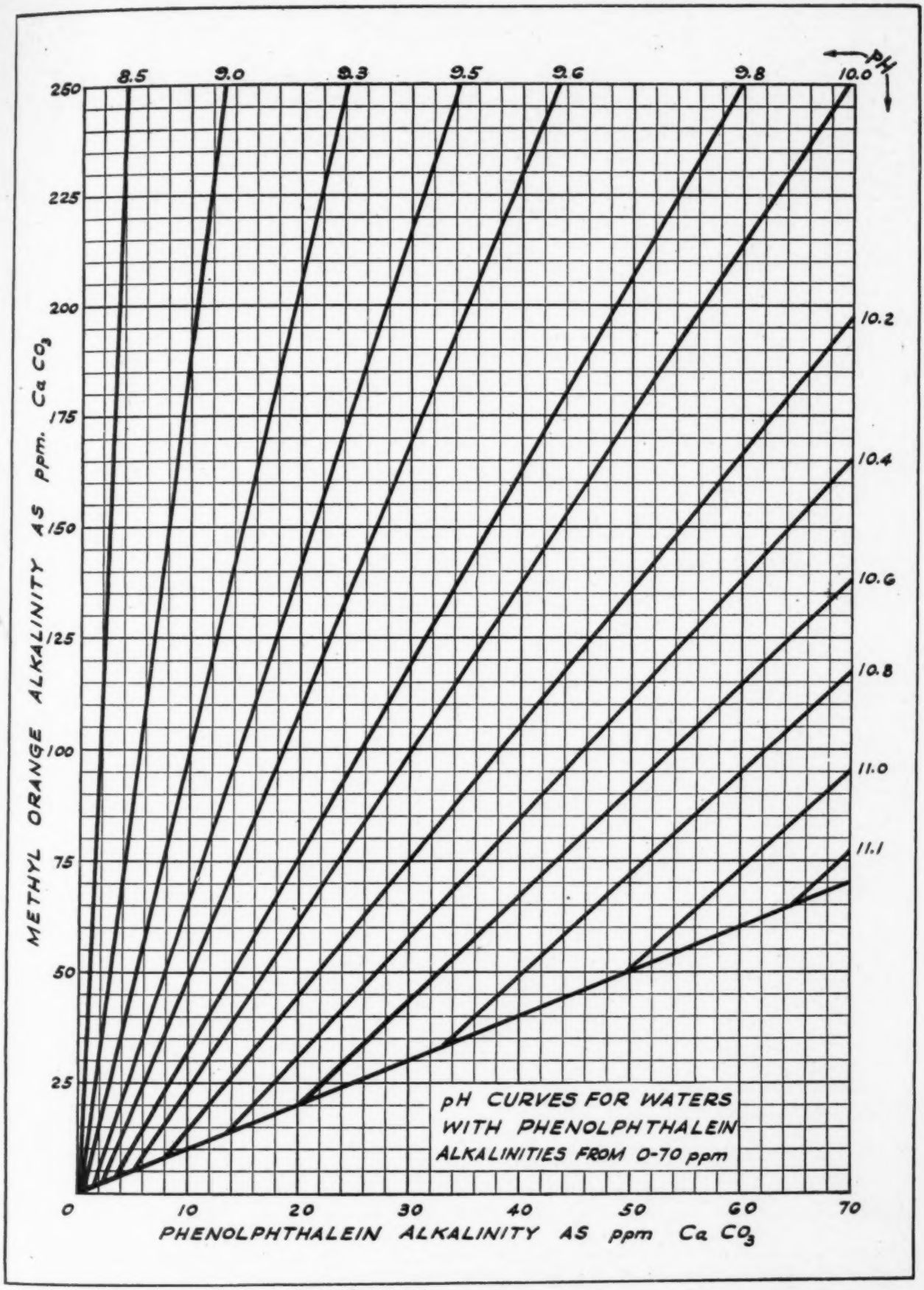
*Reproduced from the reference work "pH and Its Practical Application"—LaMotte, Kenny & Reed—(Williams and Wilkins, Publishers, Baltimore, Md.)

pH CONVERSION CHART

NOTE: *This chart has an especial usefulness in determining free carbon-dioxide content of waters without making the tedious and frequently inaccurate CO_2 titration. Alkalinity and pH readings are more easily and accurately made. To find CO_2 content —Locate pH value diagonal; follow it to intersection with alkalinity value vertical. The horizontal line passing through this same point reveals the correct free CO_2 content. Courtesy Nicholas S. Hill Associates, New York City.*



EFFECT OF CARBONATE AND BICARBONATE ALKALINITY ON pH



From Permutit Company's Data Book

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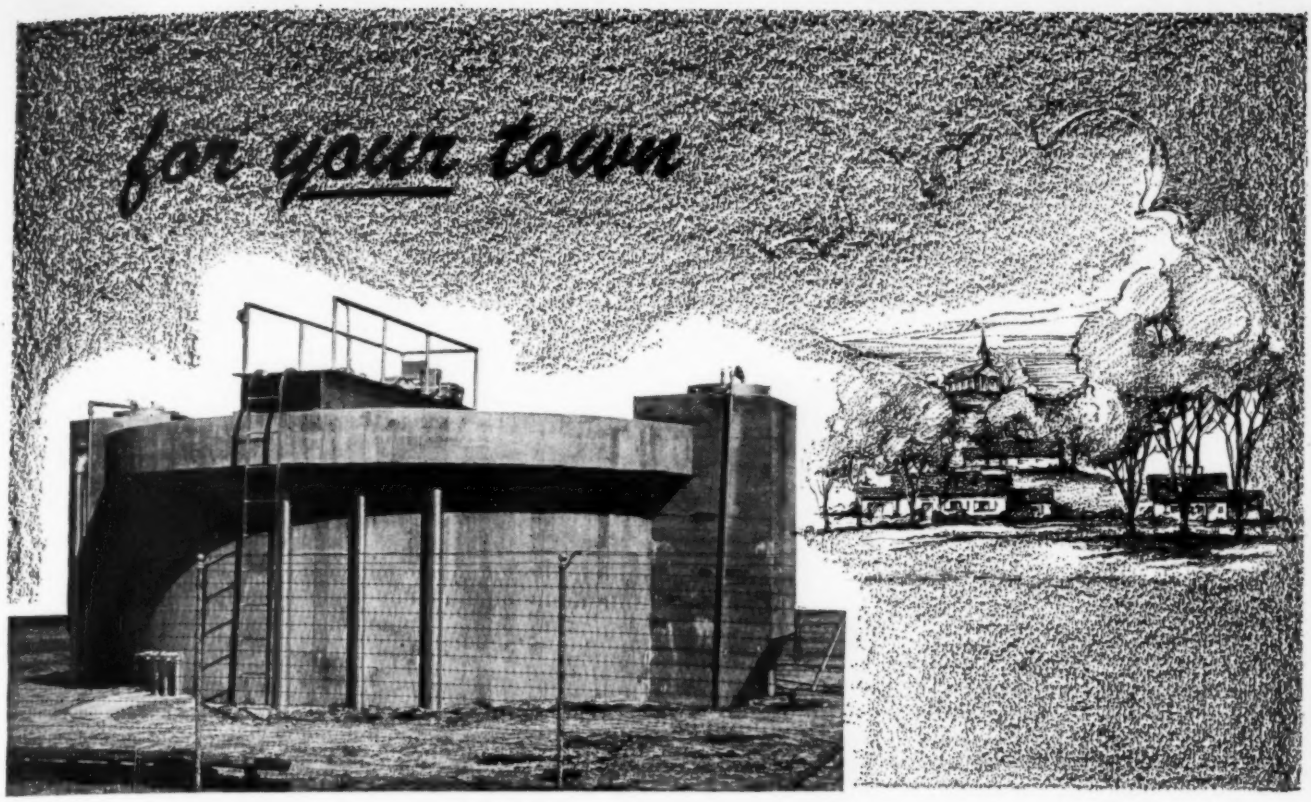

THE DORR CLARIGESTER—A COMPLETE PRIMARY TREATMENT PLANT

FOR populations ranging from 500 to 5000, the Dorr Clarigester provides complete primary treatment in a single tank. Actually, it is a self-contained, two-story separate sludge digestion plant—sedimentation taking place in the top compartment and sludge digestion in the lower.

All the advantages of big plant standards are incorporated in the Clarigester—scaled down for small plant use. Operation is mechanical from start to finish with easy to control, proven Dorr units. In the lower compartment, Digestion can be heat-controlled without undue heat loss—a fact amply demonstrated by installations operating satisfactorily through severe Canadian winters.

If primary treatment is sufficient the Dorr Clarigester is the whole plant—giving removals of up to 70% suspended solids and 30 to 45% reductions in B.O.D. If secondary treatment is desired, simply add Trickling Filters, a Biofiltration System, Chemical Precipitation or Activated Sludge. Such a combination will of course give complete treatment—and do a bigger and better job.

Over a hundred Dorr Clarigesters are now in operation at both military and municipal installations in the U. S. and Canada. Write now for bulletin #6691-C—it contains complete information.

Why the Clarigester

- Less costly—one tank does the work of two.
- Completely mechanical—all solids handled by proven Dorr mechanisms.
- One motor drive unit—no sludge pump, interconnecting piping or valves to manipulate.
- One point of feed, overflow and discharge.
- No scum or foam due to mechanical stirring in Digester.
- Gas can be utilized for sludge heating.

DORRCO

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RESEARCH ENGINEERING **DORR** EQUIPMENT

ADDRESS ALL INQUIRIES TO OUR NEAREST OFFICE

THROW IN YOUR CHLORINATION RESERVES

Perhaps wartime conditions are crowding your water system to its limit. Congestion in population, and factories working double shifts, may be loading your treatment facilities beyond their normal capacity. Under such conditions, don't overlook the *reserve* possibilities of W&T Chlorinators to relieve the strain on your treatment plant.

Prechlorination may be used to help reduce the load on filters and to eliminate slime deposits that may be impeding the flow in pipelines or valves. Break-point chlorination may enable you to draw on additional sources of water that otherwise would not be suitable to use. If emergency supplies must be used without complete treatment, adequate chlorination will assure safety in any event.

The chances are that your present W&T Chlorinators, including stand-by units, have capacity adequate for this *reserve* service. If not, inexpensive adjustment may provide this extra capacity.

Even though your problem may be a highly individualized one, your Wallace & Tiernan Representative is familiar with so wide a variety of situations where W&T equipment has provided the reserves to meet unusual demands that he can give valuable constructive suggestions. Why not get in touch with him today? SA-149